

BOUNDARIES AND BRIDGES IN RANGELAND SOCIAL-ECOLOGICAL  
SYSTEMS: STUDIES OF COLLABORATION, INNOVATION, AND  
INFORMATION FLOW

by

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## ABSTRACT

Boundaries and Bridges in Rangeland Social-Ecological Systems: Studies of  
Collaboration, Innovation, and Information Flow

by

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This dissertation assesses the state of inter-agency communication and collaboration in rangeland management through three case studies in the Western U.S. Because public rangelands are managed by a mosaic of federal, state, and local entities, social system connectivity is required for resilient rangeland management. As such, it is important to understand potential barriers to collaboration across the social system and identify opportunities for diminishing these barriers. The three case studies of this dissertation examine 1) inter-agency innovation adoption barriers for land managers in the Great Basin, 2) cross-boundary collaboration in mule deer management in Southeastern Utah, and 3) cross-boundary collaboration in rehabilitation following a wildfire spanning portions of Southwestern Idaho and Southeastern Oregon. In the first case study, thematic analysis of interviews, surveys, and a focus group, as well as social network visualization, was used to determine how adoption of two rangeland management innovations facilitating multi-agency monitoring and adaptive management is impacted by innovation, individual, organizational, and external-level adoption

constructs. In the second case study, social-ecological network analysis was used to assess potential problem areas in mule deer cross-boundary collaboration and found that a few key individuals are responsible for the majority of collaborations. In the third case study, thematic analysis of interviews and social network visualization was used to study the social dynamics behind a post-wildfire cross-boundary collaboration rehabilitation effort spanning portions of Southwestern Idaho and Southeastern Oregon. The results from this study indicate that national policy decisions, resulting from administration shifts, can heavily impact local collaboration and agencies' ability to engage in long-term monitoring projects and maintain collaborative relationships.

All three case studies of this dissertation provide an in-depth examination of how individuals within agencies are navigating inter-agency relationships, what obstacles are still present for further collaboration, and potential bridging opportunities for abating these obstacles.

(181 pages)

## PUBLIC ABSTRACT

### Boundaries and Bridges in Rangeland Social-Ecological Systems: Studies of Collaboration, Innovation, and Information Flow

Gwendŵr R. Meredith

Public rangelands are managed by a mixture of federal, state, and local governments. Often, these groups are charged with managing adjacent lands that are part of the same greater landscape. To do this effectively, communication and collaboration is required. This dissertation examines federal, state, and local agencies' level of communication through three projects.

The first project examined barriers to agencies adopting management tools from each other. I found that individuals within agencies were mainly staying within their own agency when seeking advice, so individuals were not communicating about tools or their findings across agencies. Furthermore, agency policies and fear of being sued restricted individuals' ability to adopt management tools. The second project studied how land and wildlife managers in Southeastern Utah work together, or not, in managing mule deer populations that migrate to and from land managed by different agencies. I found that managers are working together to manage mule deer populations, but there are only a few individuals that tie everyone together. The third project looked at how federal, state, and local governments work together to rehabilitate lands after a wildfire that burned parts of Southwestern Idaho and Southeastern Oregon. I found that policy decisions at the federal level can heavily impact who works together and when.

All three projects revealed that there are still barriers to federal, state, and local governments working together to manage the same landscape. However, the results from this dissertation also highlight opportunities for bridging the gap between agencies and, ultimately, improving management of rangelands.

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# CHAPTER I

## INTRODUCTION

Public rangelands are managed to provide multiple ecosystem services for various segments of society (Havstad et al., 2007); however, managing these various ecosystem services simultaneously will inevitably entail making tradeoffs to balance conflicting demands while maintaining a resilient social-ecological system. Making these tradeoffs requires an understanding of the connections between social and ecological systems and how those linkages are maintained or manipulated. All too often, however, socio-political boundaries do not account for ecologically connected landscapes (Kark et al., 2015). The spatial scale mismatch between administrative boundaries and ecological connectivity effectively fragments landscapes into separately managed parcels. Cross-boundary collaboration between the various separate social entities in an ecologically connected landscape is a way of matching the social system to the ecological one (Guerrero et al., 2013). Examining social interaction patterns that affect cross-boundary collaboration is useful in understanding why a scale mismatch might persist and point toward mechanisms for improving communication across boundaries. My research sets out to study cross-boundary collaboration and communication between rangeland management professionals to understand how that may inform the adoption and diffusion of innovations and management at ecologically relevant scales.

### **Background**

Rangeland is a type of landscape composed primarily of grasses, grass-like plants, forbs, or shrubs and includes natural grasslands, savannas, shrublands, many deserts,

tundras, alpine communities, marshes, and meadows (Society for Range Management, 1998) (Fig. 1.1). Rangelands are characterized by low and variable precipitation, nutrient-poor soils, high spatial variability in vegetation, and low net primary productivity (Havstad et al., 2007). However, these landscapes do provide a variety of provisioning, regulating, cultural, and supporting ecosystem services for human use. Traditionally rangelands were sources for food and fiber provisioning services such as US beef, sheep, and goat production. Increasingly researchers, land managers, and interest groups also highlight rangelands' importance in carbon sequestration, water quality, wildlife habitat, and biodiversity conservation (Havstad et al., 2007).

There are estimated to be over 760 million acres of public and private rangelands in the United States (U.S. Forest Service, 1989), most of which is in the West. The National Research Council (1994) estimates that about 50% of U.S. rangelands are privately owned, 43% are federally managed, and the remainder are administered by state and local governments. In the Great Basin, the percentage of public land is even higher with 70% of the land managed as a public resource (Torregrosa and Devoe, 2008). The Bureau of Land Management administers anywhere from 155-258 million acres of rangeland, depending on the definition of rangeland (Bureau of Land Management, 2019a, 2019b), and the United States Forest Service manages approximately 96 million acres of rangeland (U.S. Forest Service, 2019). Thus, the management regime of rangelands is an amalgamation of actors spanning federal, state, and local scales.

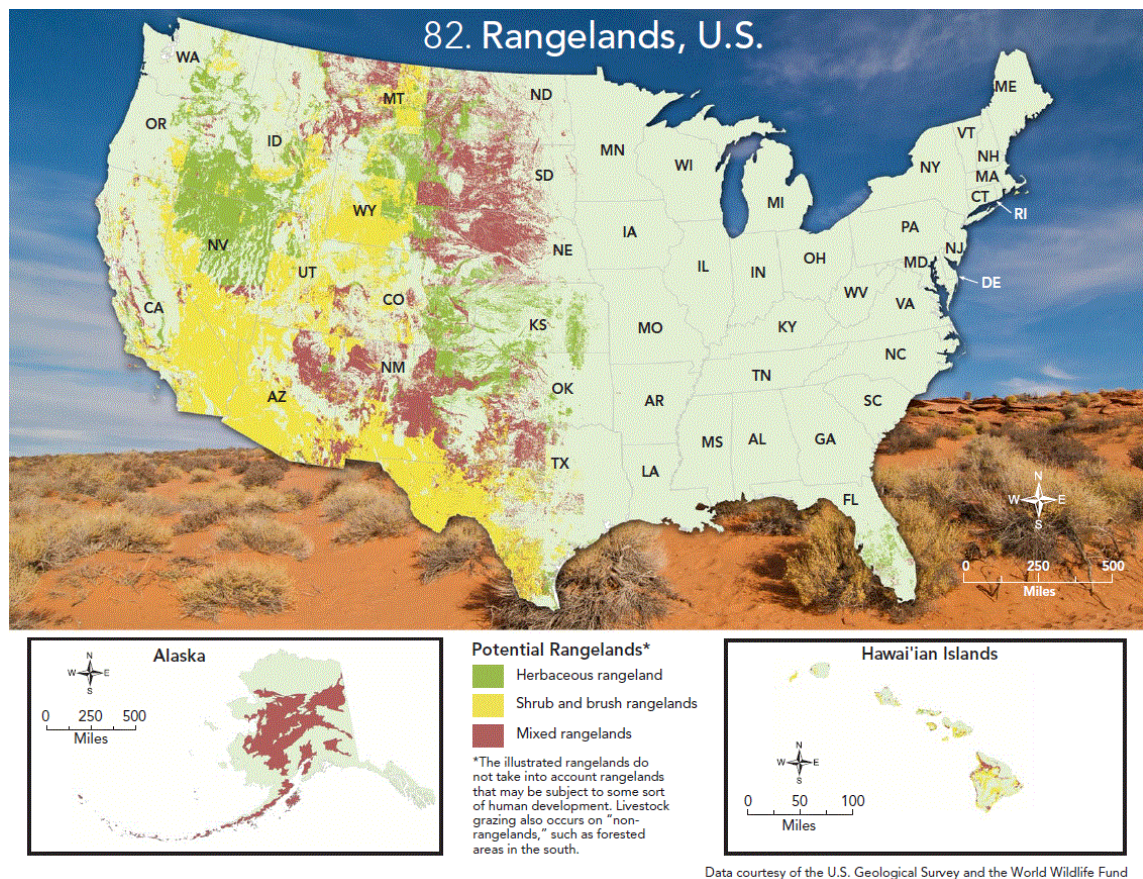
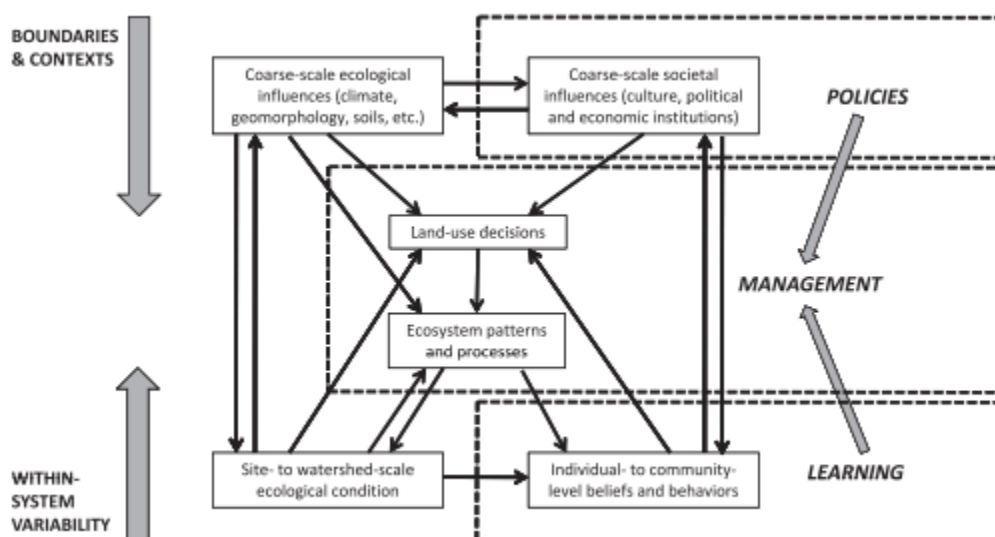


Figure 1.1. Map of U.S. rangelands (Mulvaney, 2013).

Federal land managers from the BLM and USFS have the difficult task of administering multiple-use management policies that are designed to meet diverse and often competing interests such as: tourism & recreation, energy development, timber harvesting, and livestock grazing. Managers are thus forced to make decisions based not only on ecological considerations but also considering the economic, institutional, and societal components of that problem. Although Stoddart, Smith, and Box (1975) warned that the changing demands of citizens was as crucial as the 'science' for sustaining public land grazing, it was not until the early 1990s that the academic field of rangeland social science began to take off. These early studies were focused on what society demanded from rangelands and how to influence those beliefs (Brunson and Steel, 1996; Huntsinger

and Hopkins, 1996; Kennedy et al., 1995). More recently, however, rangelands have been studied as interdependent social-ecological systems. Brunson (2012) created a conceptual multi-scalar model of rangeland social-ecological systems depicting how rangeland ecosystems and human systems are linked through bottom-up and top-down processes (Fig. 1.2).



*Figure 1.2.* Brunson's (2012) conceptual model of rangeland social-ecological systems. Brunson's (2012) conceptual model of rangeland social-ecological systems. <https://doi.org/10.2111/REM-D-11-00117.1>. Creative Commons Attribution-NonCommercial-No Derivatives License (CC BY NC ND)

The shift to studying rangelands as social-ecological systems is a result of changing management paradigms from ecosystem management to resilience-based management. While the goal of ecosystem management is to preserve coupled human and natural systems in an optimal state (Endter-Wada et al., 1998; Grumbine, 1994), resilience-based management seeks adaptive social and ecological systems that can withstand shocks and maintain critical functionality and processes without promotion of

one optimal state (Chambers et al., 2019; Walker and Salt, 2006). Social processes that promote or degrade ecosystems, and ecological processes that have cascading impacts to humans, directly or indirectly, occur at multiple scales and are difficult to disentangle (Hruska et al., 2017). As such, social-ecological systems are often studied as complex adaptive systems. Complex adaptive systems have a multitude of components that adapt and/or learn as they interact (Holland, 1992). In theory, complex adaptive systems should enable adaptation to ecological and social change, thereby increasing the overall resilience of the social-ecological system (Hruska et al., 2017). A resilient rangeland is not necessarily one of good or bad quality. In fact, degraded rangelands with high fire return intervals and a preponderance of invasive annual grasses, may be more resilient to change (i.e. restoration/rehabilitation) than more productive rangelands (Cote and Nightingale, 2012). Managing desirable resilient rangelands requires not only adaptable ecological processes, but also adaptable social processes. Resource-dependent communities and land management agencies must adapt to changing conditions as well to promote a resilient rangeland social-ecological system.

Key to resilience-based management is adaptive co-management of landscapes in which managers act together, learn from their combined actions, alter actions if necessary, and iteratively repeat in order to complete the learning process (Holling, 1978; Plummer et al., 2012). Thus, understanding how land managers are sharing information and innovations is fundamental to promoting resilience-based management. In fact, Brunson (2012) stated that improving our understanding of rangeland social-ecological systems, one component of which is the social system, is crucial to successful resilience-based management.

However, the existence of agencies that are isolated from each other and entrenched in their own bureaucracies that fragment knowledge and impede information flow lead to the production of poor decisions (Cortner and Moote, 1999). Bestelmeyer and Briske (2012) acknowledge the challenge of ‘siloed’ agencies and suggest that landscape-scale collaborative projects would both serve a more diverse group of stakeholders and increase the likelihood of successful management outcomes. This dissertation aims to further understanding of one component of rangeland social-ecological systems- information sharing and collaboration networks between land managers that facilitate landscape-scale inter-agency collaborations.

### **Research Objectives**

Western U.S. rangelands are managed by a multitude of private, state, and federal entities which may or may not communicate with each other. With connected landscapes managed in disconnected parcels, cross-boundary collaboration and the increased social capital inherent to good collaborations are required to manage entire landscapes. The overall objective of my research is to examine barriers to effective cross-boundary collaboration and communication across agencies and examine possible solutions. To fulfill my research objectives and better understand how rangeland managers communicate and collaborate across jurisdictions, I explore three different research projects surrounding (1) adoption of rangeland management innovations (2) mule deer management, and (3) post-wildfire rehabilitation efforts. Utilizing a mixed methods approach including thematic analysis of interviews and social network analysis, this research aims to assess inter-agency collaborative management of rangelands across three separate case studies.

## Literature Review

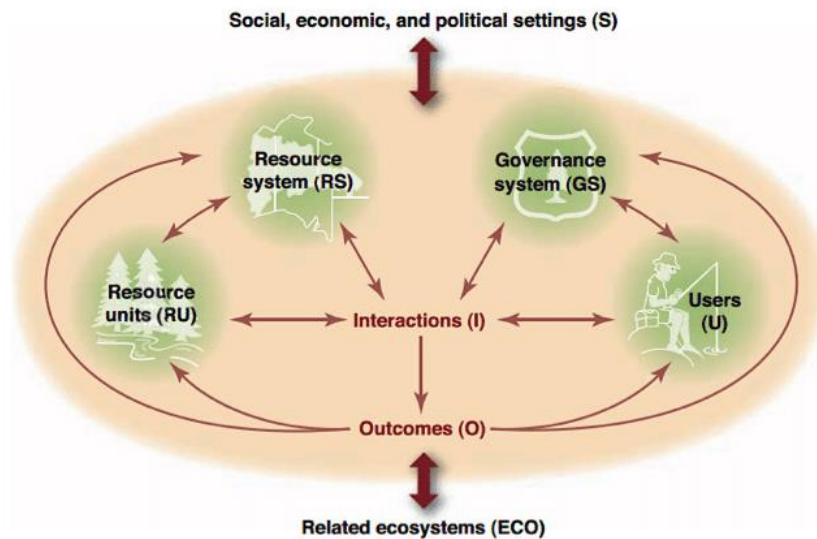
### *Social-ecological systems approach*

Social-ecological systems (SESs) were defined by Berkes and Folke (1998) as complex, integrated systems in which humans are part of nature. Later, other researchers would redefine the term to emphasize the interdependence of social and ecological systems whereby social-ecological systems are more than just humans embedded in ecological systems or ecosystems embedded in human systems (Walker et al., 2006). SES approaches are contrary to the older, reductionist approach to studying ecological or social systems in which they are broken down into their component parts and it is assumed that small-scale patterns hold at larger scales (Inchausti, 1994). Until relatively recently the reductionist approach was dominant and the area of overlap between the social and natural sciences was very limited. For the most part, ecological studies excluded humans from their studies and social science studies ignored environmental factors. The SES approach rejects the delineations between social and ecological systems and instead posits that they compose a complex adaptive system inextricably linked via feedback mechanisms (Berkes et al., 2008).

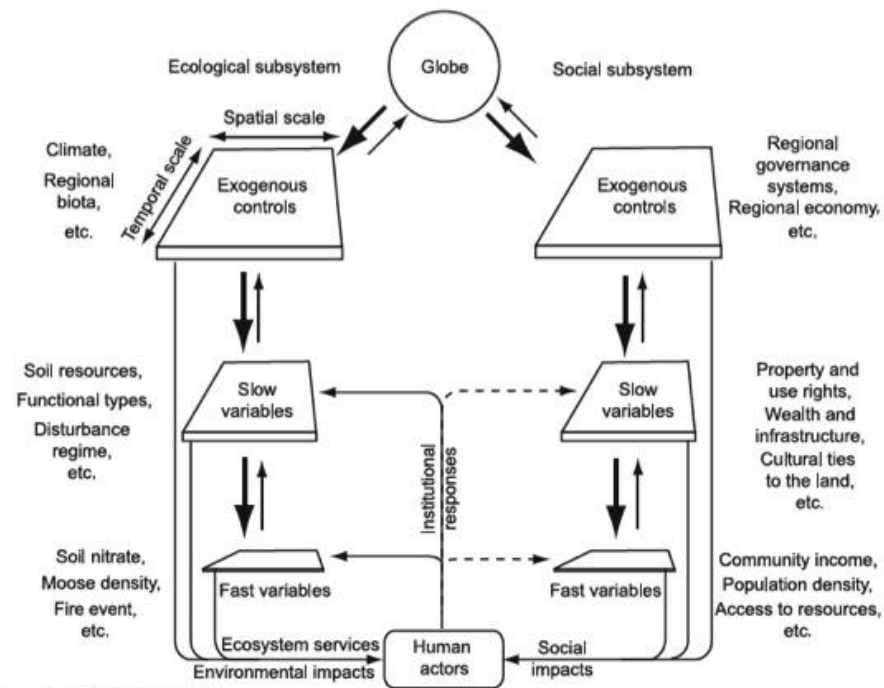
Norberg and Cumming (2008) highlight the similarities between complex systems theory and SESs, such as nonlinearity, uncertainty, emergence, scale, and self-organization. There is general agreement that the study of SESs originated from complex adaptive systems theory with additional conceptual foundations adopted from the studies of resilience, robustness, sustainability, and vulnerability. Resilience is a key component of sustainable SESs because it is a measure of a system's ability to adapt to novel changes and transformations. There are many SES conceptual frameworks used to



manage for resilience. Ostrom (2009) condenses SESs into a four sub-unit framework composed of resource units, resource systems, governance systems, and users with exogenous forces external to the model (Fig. 1.3). Chapin et al.'s (2006) framework splits the globe into social and ecological subsystems with both slow and fast variables interacting with exogenous controls (Fig. 1.4). Brunson's (2012) conceptual model of rangeland SESs places land-use decisions, as influenced by top-down and bottom-up ecological and societal processes, as the primary determinant of ecosystem patterns and processes (Fig. 1.2). This model incorporated 'management' to make the model more applicable to use by practitioners. However, what all of these frameworks have in common is the interrelation of social and ecological subsystems leading to outcomes that link directly back into the system.



*Figure 1.3.* Ostrom's (2009) Social-ecological systems framework. From: Ostrom, E. 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325(5939):419–22. Reprinted with permission from AAAS.



(Chapin et al 2006 PNAS)

Figure 1.4. Chapin's (2006) Social-ecological systems framework.  
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### *Landscape-scale restoration planning*

The terms landscape-scale (LS) planning, LS management, LS conservation, and LS restoration are all linked and have a holistic focus that considers the whole more than the sum of its parts. They also all have their origin in principles inherent to island biogeography theory. Island biogeography studies isolated ecosystems such as actual islands and figurative islands (e.g. mountain top communities, fragmented woodland ecosystems) and how emigration and immigration affect biodiversity (MacArthur and Wilson, 1967). Landscape-scale management and restoration focus on retaining whole landscapes or identifying and connecting already fragmented habitats. Generally speaking, landscape-scale restoration is the process by which local management actions “aggregate into a broader context that considers landscape flows and connectivity” (Menz

et al., 2013, p. 526). Often landscape-scale restoration is called for when ecosystems have been fragmented and unpredictable social-ecological contexts, involving multiple stakeholders and interests, lead to patchwork management regimes. Menz, Dixon, and Hobbs (2013) hypothesize that landscape-scale restoration is most successful in instances where both environmental and social issues are motivators.

Natural resource management at the landscape scale is important because many environmental processes occur across large areas. However, in many cases managing at the landscape-scale is hindered by administrative boundaries that do not necessarily conform to ecological boundaries (Knight and Landres, 1998). This is especially true of U.S. Western rangelands because there are often large expanses of public land managed by a single agency adjacent to lands managed by another agency.

#### *Cross-boundary collaboration*

Researchers have suggested that cross-boundary collaboration is the key to successful management at the landscape-scale (López-Hoffman et al., 2010). Thus, it is worth spending some time evaluating exactly what cross-boundary collaboration is and its potential benefits and limits. Firstly, collaboration in this context is defined as the working relationship between two or more actors with shared interest or responsibility in pursuing complex management goals (Kark et al., 2015; McNamara, 2012). Cross-boundary collaboration is then an extension of this principle that explicitly defines that the collaboration between two or more entities is taking place across terrestrial or maritime boundaries. The aforementioned definition still leaves out the degree of collaboration and indeed it can be difficult to parse out in practice. Degrees of collaboration can range from something as simple as coordination within existing policies

to creating new collaborative ties outside what policy dictates to the point that administrative boundaries are blurred (Kark et al., 2015).

The logic behind cross-boundary collaboration is that the whole is greater than the sum of its parts. Many studies have presented the advantages of coordinating conservation efforts (Bladt et al., 2009; Gordon et al., 2013; Rodrigues and Gaston, 2002). The idea is that cross-boundary collaboration is essentially large-scale conservation because a greater area of an ecological landscape is effectively being managed as one rather than several land patches. Particularly when resources cross boundaries within the same landscape it is beneficial for all actors to communicate so there is no spatial mismatch at the management scale (Guerrero et al., 2013).

While many posit that cross-boundary collaboration is mainly advantageous, there are also potential shortcomings to acknowledge. Collaboration across administrative boundaries often requires more resources and logistical complexity than independent management (Westing, 1998). Transfer of power from local managers to larger-scale, regional actors, can create a situation where cross-boundary collaboration bypasses local actors and enhances top-down decision-making, creating apathy or even antagonism among locals (Rodríguez et al., 2007). However, Robinson et al. (2011) posits that this challenge is scale-dependent since larger collaborations are typically forged through formal mandate while smaller efforts rely on local social networks. Similarly, Beever et al. (2014) reported that large-scale collaborations with many collaborating entities are more likely to experience turnover or change in partners' roles, affecting lasting coordination among the organizations. Another risk associated with cross-boundary collaboration is that one or more entities may become free riders on the others (White et

al., 2012). Reciprocity is a defining feature of collaboration after all. Yet another deterrent presents itself if the benefits of the collaboration are not observable to one or more of the collaborative parties. Lack of observable outcomes can lead to disinterest or discontent to the point that the collaboration is disbanded. A final challenge to cross-boundary collaboration is that, like landscape-scale conservation, it often forms around biodiversity hotspots. The discipline's attention to species richness is sometimes at the expense of local, genetically unique species or species of cultural significance to the area (Kareiva and Marvier, 2003). However, when stakeholders are integrated into the cross-boundary collaboration process at all scales from the beginning, these risks may be ameliorated (Kark et al., 2015).

### *Social capital theory*

Social capital theory has developed as an umbrella concept that has been used by sociologists, political scientists, economists, and organizational theorists for decades (Adler and Kwon, 2002). Social capital is roughly defined as the “goodwill that is engendered by the fabric of social relations [...] that can be mobilized to facilitate action” (Adler and Kwon, 2002, p. 17). Social capital theory reflects a feature of social life in which connections of one kind can be used for different purposes (Coleman, 1990). The theory has been used to inform studies on community life, democracy, economic development, education and schooling, public health, and families (Jackman and Miller, 1998; Portes and Sensenbrenner, 1993; Woolcock, 1998). Social capital theory is often also invoked to inform problems of collective action.

Social capital is a product of the social structure actors are located within (Adler and Kwon, 2002). When there is a flow of resources, such as information, across a social

structure some actors are better situated than others to receive this resource. Because social networks are a common methodology used to study the presence and potential effects of social capital it is often difficult to separate the two terms entirely (Bodin et al., 2011). Social capital theory is also closely linked to social influence theory, the idea that two actors sharing a connection will in time develop trust and influence each other (Friedkin, 1998). Since trust is so crucial to lowering the transaction costs of forming connections, some definitions of social capital go beyond focusing on the structural position of individuals to also include the reciprocity of those connections (Coleman, 1990).

There are three main types of social capital: bonding, bridging, and linking social capital (Burt, 2000; Coleman, 1990). Bonding social capital arises from the connectivity of members of a cohesive social group and arises due to homophily, the tendency to associate with similar others (McPherson et al., 2001). Bonding social capital fosters the generation of trust, creation of common norms, and facilitation of communication (Borgatti et al., 1998; Burt, 2000; Coleman, 1990). A second form of social capital, bridging social capital, arises from connectivity across social groups and develops in response to information and innovation seeking (Lin, 2017). Bridging social capital promotes interactions across heterogeneous groups that create opportunities for the generation of new knowledge (Reagans and McEvily, 2003). Linking social capital facilitates relationships between entities who are interacting across an institutionalized power gradient (Woolcock, 2001). Finding a balance between bonding, bridging, and linking social capital is important for the governance of natural resources. Too much bonding social capital can lead to homogeneity and stagnation, too much bridging social

capital can dissolve trust and efficient communication, and too much linking social capital can lead to nepotism and corruption (Bodin and Crona, 2009; Onyx et al., 2007). In theory, ideal collaboration occurs when there is a balance of bonding, bridging, and linking social capital within the network (Bodin and Crona, 2009; Woolcock, 2001).

### **Overview of the Dissertation**

To achieve the research goals of this dissertation, I completed three different research projects to address questions about the state of inter-agency communication and collaboration in rangeland management. This dissertation is organized into three main content chapters, Chapters II, III, IV. Each chapter is designed to yield a publishable paper targeted to a specific academic journal.

Chapter II examines innovation diffusion as a form of inter-agency communication by assesses how two rangeland management innovations facilitating adaptive management are shared within and between land management agencies in the Western U.S. Understanding to what extent agencies share rangeland management innovations sheds light on their potential to integrate knowledge systems other than their own. Using thematic analysis and network visualization I identify innovation traits, individual-level, organizational-level, and external system-level adoption constructs for both innovations. Innovations that are compatible with management needs, user-friendly, have an observable relative advantage over current processes, and can be adopted without loss of flexibility are more likely to be successful. Individuals within the population interviewed about the IIRH show a shortage of bridging social capital. At the organizational-level, funding streams and inflexible agency policies pose a barrier to adoption processes. Lastly, at the external system-level, political pressures and a culture

of litigation impact adoption decisions. However, innovation champions at any level of the agency hierarchy have the power to promote adoption of innovation that can in turn support flexibility in agency decision-making and adaptive co-management.

Chapter III examines how agencies work together to manage lands connected by a migratory species, mule deer, in southeastern Utah. This study offers a more tangible collaborative management problem because mule deer travel between lands administered by different federal agencies. Using social-ecological network analysis, I assess a moment-in-time network of collaborations between different land and wildlife managers as well as the mule deer migration patterns. I find evidence of collaboration across boundaries, but effectiveness and robustness of the network may be reduced due to a lack of information brokers. Hence, I highlight the need for redundancy in information brokers, which can absorb the impact of a potential network disturbance.

Chapter IV explores the social dynamics behind a post-wildfire collaborative rehabilitation effort to reveal how a social system changed around a rapidly shifted ecological system. Using thematic analysis and network visualization, I determine that national-level policy decisions fostered local-level collaboration and that individuals repurpose relationships to suit new collaborations as they arise. While organization-level barriers to collaboration were found, interviewees emphasized the importance of bottom-up processes as a way to incrementally change organizational culture.

All three of these projects provided insight into how managers make restoration and rehabilitation decisions, the level of collaboration they seek from within and outside their own agency, the barriers they face in forming those partnerships, and the impact of the political arena on those decisions. Two of the three studies identified common



organizational-level barriers to communication and collaboration but also highlighted the perceived significance of individual, bottom-up, changes to alter these larger organizational-level constraints. The third study, examining mule-deer collaborative management, showed that social-ecological network cohesion depended on a few key managers. This dissertation underscores the importance of the ‘individual’ and reveals several opportunities for improving communication and collaboration between land managers across the West.

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## CHAPTER II

### MANAGEMENT INNOVATIONS FOR RESILIENT PUBLIC RANGELANDS: ADOPTION CONSTRAINTS AND CONSIDERATIONS

#### **Abstract**

Maintaining healthy rangeland ecosystems requires adaptive co-management at the landscape scale. Because the majority of western rangelands are publicly owned, it is critical that federal land management agencies work together in generating and sharing information. Promotion and communication of rangeland management innovations among agencies is one means of sharing information. Two rangeland management innovations, the Weather-Centric Restoration Tool and Interpreting Indicators of Rangeland Health, which identify landscape condition and facilitate proactive management, were studied in order to better understand agency adoption decisions and barriers to diffusion of the innovations across agencies. Using a mixed qualitative methodology, we interviewed land managers across the floristic Great Basin and in Southeastern Utah responsible for making or advising rangeland management decisions. Using thematic analysis of interview with all participants and social networks of land manager connections in Southeastern Utah, we were able to identify variables at the innovation, individual, organization, and external system levels that affect innovation adoption and diffusion across agencies. In line with previous research, desirable innovation traits were related to five constructs: complexity, relative advantage, compatibility, trialability, and observability. Agency siloing was found to be the biggest factor affecting individual and organization level adoption decisions. The external socio-

political system was also found as a driver of organization-level barriers: funding streams, legal considerations, and differing institutional cultures between agencies. While management innovations are hindered by these barriers, there is also the potential for them to serve as promoters of institutional change and reshape these constraints. However, reshaping constraints requires 1) innovation champions and 2) incremental bottom-up and 3) top-down processes.

## **Introduction**

Resilience-based management of rangelands is required to ensure sustained production of range-based ecosystem services in an era of rapid social-ecological system (SES) change (Bestelmeyer and Briske, 2012). Because of changing climatic conditions, rangelands are facing stressors that will require adaptation and transformation of SESs. Resilience-based management strategies are proposed as a means to maintain rangelands' use for human well-being through the adaptation and transformation process. However, our limited knowledge of how the ecological system will respond to different management approaches and, reciprocally, how the social system will react to ecosystem changes, poses a challenge to resilience-based management. Adaptive management was proposed as a response to this challenge as early as the 1970s. Assuming incomplete knowledge, adaptive management uses iterative experimental management, reassessment, and refinement as a means to produce best practices (Holling, 1978). Resilience scholars now often refer to adaptive co-management, focusing more on the social aspects of the management process (Bodin et al., 2011). In adaptive co-management it is key that land managers collaboratively develop strategies that improve the SESs capacity to adapt or transform in response to change (Brunson, 2012; Walker et al., 2006). One way to

promote adaptive co-management is to build social networks that improve information flow and subsequent innovation so that thresholds are detected before they're crossed (Brunson, 2012). However, there are barriers to building and transferring information across networks of land managers. This study tracks two rangeland management innovations which could serve as conduits of information, identifies barriers to their adoption or diffusion, and suggests potential approaches for lessening these constraints.

### *Rangeland Innovation Adoption Constructs*

An innovation can be defined as anything material or conceptual that constitutes a new idea, or an idea perceived to be new by the social system. Diffusion is then a form of communication about that new 'idea' among members of the social system (Rogers, 2010). While it is easy to think of diffusion as a one-way process, that is rarely the case. Characteristics of both the adopters and the innovation are changing throughout the process as more information is made available. As such, how any innovation is adopted and diffuses through a social system is hard to pinpoint, but understanding the characteristics of the (1) innovation, (2) individual potential adopters, and (3) organizational and (4) external system in which adoption decisions are being made can help clarify the problem.

#### *1. Innovation traits*

Key to understanding the diffusion of innovations are the five perceived innovation attributes that affect adoption: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2010). The relative advantage of an innovation is the degree to which it is perceived as better than what it is replacing or improving upon. Compatibility is the degree to which an innovation already fits your needs and aligns with

your norms, values, and beliefs. Complexity is essentially a measure of how useable an innovation is. Trialability is the degree to which the innovation can be tried out without much investment. The observability of an innovation is how visible it is to others as a social signal (Rogers, 2010). The bulk of innovation diffusion studies have focused on these five attributes and have been applied to campaigns as varying as marketing birth control to promoting farmers' use of hybrid seed corn (Rogers and Kincaid, 1981; Ryan and Gross, 1943). However, other frameworks have emerged that slightly alter Rogers' theory of innovation attributes. A review of adoption of conservation practices by rural landholders modified Rogers' innovation attributes by grouping compatibility and complexity as factors affecting relative advantage and observability as a variable affecting trialability (Pannell et al., 2006). All five attributes, along with landholder specific variables such as "the impact of the innovation upon the family lifestyle," were identified as factors impacting landholders' adoption of conservation practices (Pannell et al., 2006).

## *2. Individual-level adoption constructs*

When there is a flow of resources, such as information, across a social structure some actors are better situated than others to receive this resource. Social capital is a product of the social structure within which actors are located (Adler and Kwon, 2002). Social capital theory is also closely linked to social influence theory, the idea that two actors sharing a connection will in time develop trust and influence each other (Friedkin, 1998). An individual's position in the social structure can impact their social capital and thus their access to information and power to diffuse that knowledge. There are three main types of social capital: bonding, bridging, and linking social capital (Burt, 2000;

Coleman, 1990). Bonding social capital arises from the connectivity of members of a cohesive social group and arises due to homophily, the tendency to associate with similar others (McPherson et al., 2001). Bonding social capital fosters the generation of trust, creation of common norms, and facilitation of communication (Borgatti et al., 1998; Burt, 2000; Coleman, 1990). A second form of social capital, bridging social capital, arises from connectivity across social groups and develops in response to information and innovation seeking (Lin, 2017). Bridging social capital promotes interactions across heterogeneous groups that create opportunities for the generation of new knowledge (Reagans and McEvily, 2003). Linking social capital facilitates relationships between entities who are interacting across an institutionalized power gradient (Woolcock, 2001). Finding a balance between bridging, bonding, and linking social capital is important for the governance of natural resources. Too much bonding social capital can lead to homogeneity and stagnation, too much bridging social capital can dissolve trust and efficient communication, and too much linking social capital can lead to nepotism and corruption (Bodin and Crona, 2009; Onyx et al., 2007). In theory, ideal collaboration occurs when there is a balance of bonding, bridging, and linking social capital within the network (Bodin and Crona, 2009; Woolcock, 2001).

### *3. Organizational-level adoption constructs*

When innovation-adoption decisions are made within organizations, individuals have additional factors to consider. An organization is a “stable system of individuals who work together to achieve common goals through a hierarchy of ranks and a division of labor” (Rogers, 2010). In the context of this paper, organizations are primarily land management agencies. Within these agencies many factors can impact adoption,

including institutional culture, legal obligations, funding streams, incentive systems, and systems of academic training (Briske, 2012; Koontz and Bodine, 2008). Historically, funding timelines for Emergency Stabilization and Rehabilitation (ESR) have not been compatible with the impact of weather variability and long-term restoration goals (Hardegree et al., 2019, 2018). Iterative-contingency restoration, a potential organizational-level change promoting a shift to more proactive management, would be facilitated by innovations which detect transition to another ecological state (Hardegree et al., 2019). Another organizational-level adoption construct occurs when agencies and/or programs within agencies become siloed. This siloing impedes information flow, innovation diffusion, and hinders the potential for adaptive co-management across agency boundaries (Cortner and Moote, 1999). The more agency siloing is present, the less potential there is for disparate agencies to co-develop and utilize rangeland management innovations promoting proactive management. The centralized, hierarchical structure of most land management agencies is also a recognized impediment to resilience-based management (Bestelmeyer and Briske, 2012). Hierarchical structuring restricts lateral communication within agencies. This barrier to knowledge sharing across disciplines can hinder full adoption of rangeland management innovations and, in turn, landscape-scale adaptive management.

#### *4. External system-level adoption constructs*

At an even larger scale, there is an external system - the larger socio-political system – driving organizational traits (Wisdom et al., 2014). Social and political pressures locally, regionally, and nationally impact agencies structurally and operationally. For example, in Wright's (2010) study of impediments to the use of 'best

science' in fire management, federal fire and fuels managers cited external barriers related to the influence of 1) high-level political priorities, 2) public interest groups, 3) the general public, 4) and the role of human values in management decisions among the top five barriers. Innovation adoption decisions do not occur in a political vacuum, rather they are tempered by the larger socio-political system of the time.

## **Methods**

### *Research Approach*

This paper follows two case studies of rangeland management innovations at different stages of the design, implementation, adoption, and diffusion process, with consideration for innovation traits, individual social capital, and organization constraints as impacted by external socio-political pressures. The innovations examined were the Weather-centric Restoration Tool (WCRT) (Moffet et al., 2019) and the Interpreting Indicators of Rangeland Health (IIRH) protocol (Pellant et al., 2005). The WCRT is a website designed to offer managers help in developing best management practices for restoration under the highly variable weather conditions in the western US. The website contains a number of weather-centric restoration planning and analysis tools. It was developed in cooperation with the Joint Fire Science Program, Great Basin Fire Science Exchange and can be accessed through their website (<http://greatbasinfirescience.org>) or directly (<http://greatbasinweatherapplications.org>). The WCRT has two components: a retrospective assessment tool that helps managers understand how past weather patterns at a localized scale might have affected current conditions, and ultimately a predictive tool that will allow managers to assess likelihood of establishment of restoration plantings based on downscaled climate projections that forecast likely weather conditions



during critical growth periods. The predictive component is still under development but expected to be completed soon. The retrospective assessment of weather at a particular site has utility in informing adaptive management and long-term restoration strategies (Hardegree et al., 2019, 2018). Users can obtain site-specific restoration information by providing site location (latitude and longitude), surface soil texture, and contact information (Moffet et al., 2019). Based on that information, users are provided with data files containing: estimated daily weather parameters for the site (Abatzoglou, 2013); estimated hourly temperature and water availability at 2-cm soil depth (Flerchinger and Hardegree, 2004; Flerchinger et al., 2012) and a restoration-climatology report that synthesizes annual and seasonal information on seedbed favorability for establishment (Hardegree et al., 2003, 2013), and potential post-germination/pre-emergence mortality risk due to freezing or drought (Hardegree et al., 2016a). This innovation was selected because we could track the WCRT's evolution from design, which began in 2014, to implementation in 2018.

To understand how an already existing rangeland management innovation had diffused throughout a network of managers in one geographic region, I also examined adoption of the Interpreting Indicators of Rangeland Health (IIRH) Technical Reference Version 4 (Pellant et al., 2005). The IIRH reference was jointly created by the Bureau of Land Management (BLM), United States Geological Survey (USGS), Natural Resources Conservation Service (NRCS), and Agricultural Research Service (USDA-ARS). The IIRH protocol provides a standardized qualitative method for assessing a moment-in-time status of rangelands. Evaluators use seventeen indicators to assess three ecosystem attributes (soil and site stability, hydrologic function, and biotic integrity). The protocol

uses observable indicators to interpret and assess rangeland health, which could provide early warning signs of problems. A provisional copy of IIRH Version 5 was released in April 2018, after the completion of data gathering phase (Pellant et al., 2019). Both innovations were selected because of their generalizability to various agencies managing rangelands.

Both the WCRT and IIRH are directed at assessing current or past rangeland conditions to inform future management. Rangeland ecosystems can shift into multiple vegetation states depending on natural events, such as fire and weather, and human activities, such as management practices (Briske et al., 2008, 2005). Invasive species and increasing wildfire events are stressors that rapidly shift landscapes into another ecosystem state (Balch et al., 2013; Chambers et al., 2014; Dennison et al., 2014). Invasive plant species alter ecosystem function by reducing biodiversity and habitat for native plants and wildlife (D'Antonio and Vitousek, 1992). Due to climate change, wildfires in the western United States have increased in frequency and intensity (Balch et al., 2013; Dennison et al., 2014). Changing fire regimes and invasive plants are serious challenges to managers trying to maintain native plant and animal diversity on rangelands. For example, cheatgrass is an invasive annual species that is part of a positive feedback loop with fire. Landscapes dominated by cheatgrass burn easily, cheatgrass takes advantage of increased resource availability after the fire to seed, and the cycle repeats (Zouhar, 2003). Cheatgrass' effects on fire cycles are made more complex when factoring in unpredictable weather conditions. Climatic variables are often a significant limiting factor in management opportunities in rangeland ecosystems (Hardegree and Van Vactor, 2004). Managers are tasked with gauging the potential of a landscape unit to

transition to a more desirable state but they need tools in hand to assess that potential.

The Weather-centric Restoration Tool is an attempt to fill this gap and provide a resource for managers that facilitates the incorporation of short-term climate data into management decisions. Similarly, the IIRH protocol assessment is a tool for manager's to quickly assess landscape condition and determine whether further action is required. Both innovations are intended to add to the managerial toolbox and promote protection of rangelands.

This study uses a case-study approach to assess (1) agency adoption of the IIRH protocol, (2) what properties of the WCRT managers' desire, and (3) the barriers to adoption and diffusion of both the WCRT and IIRH.

#### *Study Area*

The floristic Great Basin and southeastern Utah served as our study areas. The WCRT is designed to assist managers throughout the Great Basin; thus, interviews were conducted with individuals from across this region. The IIRH protocol is specific to rangelands but not limited to the study area we selected. We chose to study diffusion of the IIRH protocol in southeastern Utah for the practical reason of limiting the potential sample size so we could reach response saturation.

#### *Survey & Interview Protocol*

To understand how land managers make innovation adoption decisions, we chose a mixed qualitative methodology composed of key informant interviews, online and print surveys, and one focus group. A snowball sampling methodology (Noy, 2008) was used to identify additional participants after conducting initial interviews. The interview protocols were reviewed and approved by the Institutional Review Board at Utah State

University as protocols #4683 and #8630. For the WCRT data gathering, we communicated with 27 individuals responsible for making or advising rangeland management decisions from October 2014 to March 2018. Twenty-five of those respondents fit our eligibility standards and were included within our analysis.

Interviewees were private ecological consultants as well as employees of federal and state agencies and military entities. These semi-structured interviews, surveys, and focus group dialogic interactions were focused on gathering information on potential innovation traits and managers' barriers to adoption of the WCRT: 1) In what ways do you currently use online resources to inform your decisions on rangeland restoration following wildfire or non-native plant invasion? 2) How usable and reliable are the online resources you've seen for informing rangeland restoration decisions? 3) If new weather-related online management tools were available to you, are there factors that might hinder your ability to use them? For the full WCRT interview question sets, refer to Appendices I – IV. Data was gathered until no themes were observed from additional data, thus reaching saturation.

For the IIRH data gathering, we conducted 11 semi-structured interviews from June – August 2017. Two of these 11 subjects were hesitant to be interviewed in-person but did agree to email a response to my interview questions. Interviewees were employees of the Bureau of Land Management (BLM), U.S. Forest Service (USFS), and National Park Service (NPS). Because the IIRH is an innovation that has been implemented over a decade, these semi-structured interviews did not focus on desirable innovation traits, but rather on managers' barriers to inter-agency use of the IIRH. For the IIRH data gathering, we also asked managers about whom they seek for rangeland

management advice for the purpose of creating a social network to elucidate potential barriers to communication: 1) What would you say is the leading factor that led to adoption of the IIRH? 2) Do you perceive your agency adopts innovations from other agencies? Explain. 3) Whom do you go to for advice in making rangeland management decisions? For the full set of questions, refer to Appendix E. Saturation was also achieved for this portion of the study because there were few agency employees within the study area that fit our eligibility requirements and a significant portion of that study population was contacted.

Data was collected using an iterative, adaptive surveying methodology that evolved as questions were answered and new questions emerged (Didier and Brunson 2004). The focus group and interviews were conducted using an interview protocol and script but were semi-structured so that data not previously thought of could be explored. The interviews and focus group were also audio-recorded with consent of the participants and transcribed for coding. Thematic analysis was used to assess participants' desired innovation properties for the WCRT, adoption status and social network data for the IIRH, and professed barriers to innovation adoption for both the WCRT and IIRH. Thematic analysis is commonly used in qualitative research as an inductive method to systemically discovering and then examining themes in the data (Braun and Clarke, 2013). Using thematic analysis, we were able to better understand the broader context in which managers are making decisions, adding depth to the understanding of our research questions by providing answers to questions that cannot be reduced to binary terms.

## Results

### *Innovation Traits*

The Weather-centric Restoration Tool (WCRT) was in its design phase in 2014 when we started gathering data on land managers' perceptions of the potential tool. As such, it was the ideal time to research what innovation traits land managers would find desirable in the WCRT so those ideas could be incorporated in the innovation's design. For any innovation to be successful it requires a set of traits that make its adoption worthwhile for the user. All five of Rogers' innovation attributes - complexity, relative advantage, observability, compatibility, and trialability - were identified as being important for land managers' adoption of the WCRT.

The number one factor that participants mentioned as affecting their potential adoption was related to the complexity of the innovation. Participants desired the WCRT to be user-friendly with minimal complexity; as one anonymous survey respondent expressed: *"I have tried using systems like PRISM and the steps and output are too convoluted. To have a program where I can input site-specific variables and receive weather data and advice in a user-friendly format would be much appreciated."* The WCRT was created with this feedback in mind. To generate a full site report, all that is needed is the latitude, longitude, and soil texture of the site of interest.

Participants who expected they would adopt the tool desired it to be a freely accessible online tool that was regularly maintained and provided ample technical support options. They desired something similar to NRCS's Web Soil Survey, citing its user interface and output that can be understood with minimal training. Participants agreed that if the tool was an expensive software program that required extensive

training, their likelihood of adoption would be much lower. For example, one ecological consultant stated that *“if it’s the sort of thing that you could play on the web for nothing for thirty minutes, figure out how to do, and try it out, that will probably sell itself. If you have to buy it and be trained to use it, it’s going to have really limited utility.”*

The second and third factors most often cited by land managers related to the WCRT’s relative advantage over current decision-making processes and the observability of results. Specifically, some participants were wary of the predictive ability of WCRT. There is a large degree of year-to-year variability in rangeland weather which greatly affects the success of management practices (Hardegree et al., 2016b; S.P. Hardegree et al., 2012; Stuart P. Hardegree et al., 2012). The WCRT is designed to help identify those years in which you have a greater chance of success in establishing a significant proportion of seed mix species. This would help managers limit their expenditures in bad years and channel their expenditures to good years, given they had the flexibility to decide which year to plant. For several participants this was not enough of an incentive to alter the status quo management decision. As one BLM Idaho employee put it, *“We’ve always tried to stress ‘what’s the reliability?’ Understandably, the reliability is better than tossing a coin. Otherwise, why do it? But I think most managers would say, ‘Well, if it’s 60% versus 40% and we’ve got funding and need to apply it or lose it, that’s not going to be enough incentive to say we better hold off on the project.’”* While the relative advantage of WCRT is too low for some managers, the predictive ability of the tool is not entirely at fault. Other factors, such as distrust of models and inflexible funding streams, discussed below, also contribute to the perceived relative advantage of WCRT.

Managers desired to test the WCRT using hindcasting, whereby past conditions are estimated and compared to actual data from that time period. One BLM Idaho employee suggested *“Going out to some sites and backcasting the model to show ‘Here’s what it looks like today. Based on the weather conditions that we could have predicted and the management outcomes, would you change actions you took in the past?’ I think that would be a pretty valuable way to demonstrate the utility.”* This is aligned with two of Rogers’ attributes of innovations: relative advantage and observability. Before adoption, managers want to be able to observe the innovations’ advantage over ‘business as normal’ management. Generally, managers’ thoughts echoed that of this BLM Nevada employee: *“I’d want [the WCRT] to show how predictions come through to prove that there’s value in it, that actual predictions did come true.”* Currently, the developers of the WCRT are establishing the forecasting skill of the tool through hindcasting using 11 locations in the western US, including 4 in the Great Basin: Boise, Burns, Salt Lake City, and Reno. This measure of the WCRT’s quantitative utility in the Great Basin will be completed soon.

The fourth factor most often cited by land managers relates to how compatible the WCRT is with land managers’ needs, particularly in matching the scale of the output with that of their projects. Managers desired a tool where they could input the zip code or latitude and longitude coordinates and receive immediate output at a scale similar to that of their project. Adding seasonal weather forecasting, wind erosion potential, and seedbed microclimate data could improve the amount of available science at their disposal but could also complicate the output beyond usability. Providing data at a very fine scale was perceived by some as potentially convoluting the decision-making process.



A military ecological specialist voiced that *“if you are new to [Ecological Site Descriptions] they are confusing unless you’re helped. If you start adding additional information onto that you could get it so convoluted it’s not usable.”* On the other end of the spectrum, several land managers mentioned how Ecological Site Descriptions are often too coarse-grained and lacking detail; as one ecological consultant explained: *“On a lot of sites we work on there is a fine scale of variability that is absolutely critical from our restoration perspective that isn’t captured and will just be mapped as a mix of several soil types.”* Generally, respondents desired a balance between fine scale results and increased complexity. In 2019, the developers of the WCRT increased the scalability of the automated tools for points, grids, and shapefiles.

Also associated with the perceived compatibility of the WCRT was distrust of using climate model output in making management decisions. As previously mentioned, any forecasts produced with the WCRT would be probabilistic in nature. Several participants either expressed their disapproval of models or said they had co-workers that distrusted models. Models were perceived as “unproved predictions” and highly error prone. As one BLM Nevada employee put it, *“I just don’t know how effective it would be. You can’t predict the weather a month from now, let alone next spring.”* For some, failures in the past using model output made them wary of future model applications. For example, a BLM Idaho employee observed that *“There’s been enough models that haven’t worked as well as expected so I think that would be one hurdle to overcome.”* For others, their distrust of models was less clear but appeared to originate from epistemic differences.

The fifth tool trait relates to the trialability of the innovation. Participants reported that if the WCRT was made mandatory at their agency it would have an overall negative effect, because some flexibility in decision-making and management would be taken away. A military ecological specialist felt that *“if now all of a sudden this is a required tool to use, it takes my flexibility away.”* Managers want an option to try the tool but not an edict that it’s required. This challenge pertains to a variety of issues stemming from the fine balancing act between centralized governance structures and retention of flexibility at the local level.

In summary, these findings suggest that land managers prefer rangeland management decision-making tools that are user-friendly, complex enough to be scale-appropriate but not so much to convolute the data, compatible with their needs, providing observable sufficient relative advantage over status-quo management regimes, and allowing flexibility in decision-making.

The authors investigated the adoption and diffusion of the IIRH protocol after the innovation’s implementation; as such, they did not specifically collect data on desirable traits. Regardless, several interviewees brought up their perception that the IIRH lacked a relative advantage over other, more quantitative, options. The qualitative nature of IIRH was cited as a deterrent to its adoption by three interviewees. These individuals perceived the qualitative indicators to be too subjective and simplistic to stand up in court if contested. This was highlighted in disagreements between NPS and BLM employee’s perception of what constitutes varying levels of departure from the reference state. Interviewees that explicitly claimed that quantitative data would need to supplement the IIRH perceived no relative advantage to using IIRH. Rather, multiple individuals

mentioned the BLM's Assessment, Inventory, and Monitoring (AIM) strategy as a tool that is in the process of replacing IIRH. However, one of the key changes to Version 5 of the IIRH is to add emphasis on the use of quantitative measures to support evaluations and the document specifically mentions keeping standardized core methods consistent with BLM's AIM strategy (Pellant et al., 2019).

*Individual-level adoption constructs*

To understand how adoption of the IIRH protocol could be related to the social capital of land managers, a network of agency individuals was determined based on whom they solicit ideas or advice from in making land management decisions (Fig. 2.1). Fig 2.1 shows that the individuals within this study in the BLM, USFS, and NPS sought rangeland management advice and ideas from within their agency, but not from individuals at the other two federal agencies.



adoption, but it was not clear that was their primary motivation for adoption. These findings suggest that, within this context, land managers may have bonding and linking but not bridging social capital.

*Organization-level & External system-level adoption constructs*

While interviewing land managers about their potential or actual use of the WCRT or IIRH, major institutional barriers to adoption came to light. Funding streams, especially for Emergency Stabilization and Rehabilitation (ESR), were viewed as restrictive to adaptive management. A Nevada BLM employee stated that *“as far as Emergency Stabilization and Rehab, you have a short window and you need to get in there and plan on implementing right away.”* Furthermore, participants interviewed about the WCRT mentioned that while the WCRT could promote proactive management, set timelines and funding for restoration work would limit managers’ flexibility in using the tool. A military ecological specialist explicitly mentioned how funding streams restrict their decisions: *“The [WCRT] would probably be better at deciding whether or not I’m going to do a prescribed burn or control of invasive species, something I can control as opposed to something restrictive. If we’ve had a burn, I’ve got the money for that year. I have to dump the seed down regardless of what the climate model says.”* One interviewee with the Nevada USFS expressed concerns about using the WCRT for mining reclamation: *“We have a lot of mining reclamation and we have to tell them almost a couple years in advance what they are going to do.”* Whether management plans have to be decided years in advance, in the case of mining reclamation, or that season, in the case of ESR, interviewees felt restrained in what management actions they could implement using the WCRT. As previously mentioned, the WCRT requires the user to have some

flexibility in deciding what year to seed. Currently, that limits the use of the WCRT to restoration projects outside the context of ESR. However, recently the US Department of Interior lengthened the ESR time period to 3-5 years in pursuit of longer-term restoration goals (U.S. Department of the Interior, 2015).

An external system-level adoption constraint that impacted managers' adoption decisions concerning the WCRT and IIRH was political pressure, particularly concerning grazing resumption after treatments. As one BLM Nevada employee puts it, *"Grazing is always an issue, being able to allow rest for re-establishment for perennials as well as seeded species. There's political pressure not to close [allotments]."* There was the perception that regardless of seasonal weather predictions and the resulting probability of success, seeding and 'working the land' are actions that make the agency look good. There is pressure to spray herbicide and/or seed immediately after a wildfire event so that the land is available for grazing as soon as possible. Thus, participants mentioned that seeding the first fall after a fire, regardless of whether climatic conditions will be favorable to seedling establishment, is preferable because it is perceived as an active, rather than passive, management approach. Looking forward, political pressure could be a hindrance to the WCRT if the output contradicts societal demands. An ecological consultant summed this up by saying, *"Whether or not [the WCRT's] going to be used probably relates more to economics, politics, and organizational factors."*

Agency siloing, driven by institutional cultural, legal considerations, incentive structures, and systems of academic training, was the number one barrier to inter-agency diffusion of innovations. Hierarchical structuring in agencies keeps communication within agency and even sometimes restricts communication within discipline within an

agency (see BLM in Fig. 2.1). For example, one Utah BLM employee stated, *“I think if there was a [x] related question that I didn’t know, I would ask my supervisor. If he didn’t have the answer, I would ask the state [x] lead.”* Whether the symptom, or the cause, agency siloing was also related to fear of legal action for information sharing outside agency borders. Fear of legal repercussions were mentioned as a barrier to adopting any innovation originating elsewhere. As one Utah BLM employee put it, *“The BLM must follow its own protocols and guidance for sound management decisions that are defensible in court.”* Especially because the IIRH protocol is often used to assess whether grazing permits should be renewed, agency personnel participants mentioned how carefully they implement the IIRH protocol according to agency guidelines. Eighty percent of adopters altered the innovation in some form anyway, typically by adding or subtracting indicators, in order to fit their particular circumstances. Of those who reported they had not altered the innovation in any way, half cited agency policy as stifling their ability to adapt it. Generally, threats of litigation for operating outside of agency policy led managers to stay within their own agency when communicating about a management tool or approach.

Differences in training, or at least perceptions of differences, was also a factor promoting agency siloing in this context. For example, in speaking of inter-agency communication between the NPS and BLM, a Utah NPS employee saw major differences in management style: *“We don’t speak the same language. We don’t speak the same management style. They have a completely different opinion of everything. After [x] years, I still haven’t got them [BLM] to understand NPS policy. We’ve been trying to educate them to a certain extent but they tend to forget after awhile. They look at things*

*in terms of multiple use and they never met a cow they didn't like.*” Application of the IIRH protocol particularly suffers from agency siloing. Many, if not most, land managers receive training on how to assess different condition departures from a reference state; however, over time managers' perception of departure begins to align with the mission of their individual agency. For instance, individuals from the BLM and the NPS viewed each other as having differing views on indicators that should be subjective. One Utah NPS employee stated that *“where [inter-agency collaboration using the IIRH] tends to break down is in how we interpret the data that we collect or how we evaluate what the effect will be on the landscape of a certain action.”* This finding may be a result of individuals staying within their own agency for advice. As shown in Fig. 2.1, the advice network of individuals interviewed about the IIRH protocol is highly fragmented between and even within one agency. In response to a question concerning this lack of inter-agency communication, a Utah NPS employee summed it up saying, *“It boils down to different cultures and a lack of staff and money.”*

Within these siloed agencies there is still opportunity for adoption of rangeland management innovations given the presence of an ‘innovation champion’ to promote its use and overcome any resistance or indifference to the innovation. Agencies require champions to seek out and promote innovations they find useful to furthering their agency's mission. These champions do not have to be individuals at the top of the agency hierarchy. In fact, personnel at regional field offices will likely be more motivated to seeking and promoting methodological/technological innovations like the WCRT and IIRH. For example, one Utah BLM employee stated that *“The BLM has its own protocols. But, personally, I want to see anything new that comes up and how it works.”*



*When I see stuff I send it up to the state office. They go through it and start this whole process, but it's got to start on this level [field office]. If we hear something then we have to start kicking it up so they are aware of it, because most of the Salt Lake and Denver people don't get into the field so they don't see this kind of stuff."*

## **Discussion**

Land management agencies face the need to adapt to increasing uncertainty associated with climate change, biological invasions, human population growth, and other rangeland stressors. Resilience-based management has been proposed as a forward-looking strategy that seeks to maintain rangeland heterogeneity as an insurance policy against a variety of change effects (Bestelmeyer and Briske, 2012). Resilience-based management will require looking more toward the future than the past and maintaining rangeland heterogeneity as an insurance policy against a variety of climate change effects. However, paradigm shifts are exceptionally difficult to enact because they require the alteration of values and theories that have been in use for years by a professional community (Cortner and Moote, 1999).

Examining both the WCRT and IIRH allowed us to more fully examine innovation adoption processes in land management agencies. The WCRT and IIRH showcase different stages of rangeland management innovations' adoption process. In the case of the WCRT, the researchers documented the tool's progression from design to early implementation. Examining the IIRH allowed the researchers to see another stage of innovation adoption: full implementation and continuing adaptation. Both the WCRT and IIRH facilitate a change from more reactive to proactive management. The IIRH protocol gives a moment-in-time assessment of rangeland health which can provide an

early indication that lands should be monitored so that critical thresholds of ecological change are not reached. The WCRT gives land managers a chance to align future management with predicted climatic conditions. However, both the WCRT and IIRH also face institutional barriers to full implementation.

In designing technological or methodological innovations, it is key that decision support tools facilitate easy application of the information they provide. Innovations that are compatible with management needs, are user-friendly, have an observable relative advantage over current processes, and can be adopted without loss of flexibility are more likely to be successful. Additionally, as we further advance into an era of increasing technological advancement, freely available online tools will likely have an advantage over the majority of expensive licensed software and programs.

From the interviews conducted in studying both the WCRT and IIRH protocol, it became apparent that vertical communication to superiors within agency (linking social capital) was common, horizontal communication within agency (bonding social capital) was sometime lacking, and communication outside of the interviewee's agency (bridging social capital) was far less common. Insufficient bridging social capital can lead to stagnant information pools not conducive to innovation. Hierarchical decision-making structures can also limit innovation because practices that are a departure from the norm must be institutionalized at a state or nation-wide level. When this lack of bridging social capital is combined with hierarchical decision-making structures, innovation diffusion is often impeded. Additionally, funding timelines and strict agency policies that require employees to follow agency protocols precisely were a barrier to managers' cross-boundary innovation adoption. Legal restrictions that promote existing program policies

to the exclusion of other approaches suppress innovation. This reduction in flexibility in turn hinders managers' capacity for adaptive co-management.

In summary, to understand barriers to adoption and implementation of rangeland management innovations, the authors studied characteristics of the (1) innovation, (2) individual potential adopters, and (3) organizational and (4) external system in which adoption decisions are being made (Fig. 2.2). These adoption constructs are not independent of each other. In fact, these variables have a successive impact upon each other. The external environment affects the organization/agency, which in turn impacts individual land managers. If these variables are not conducive to innovation diffusion, optimizing innovation traits alone is likely not enough to surmount adoption barriers at the external, organization, and individual-level. However, optimal innovation traits in combination with land managers that act as innovation champions can reverse the direction of those successive impacts such that the organizations/agencies and external environment are affected by the innovation.



*Figure 2.2. Non-independent variables impacting innovation adoption*

Pinkerton (2007) outlines five biases that hinder adaptive co-management between agencies. These five biases are “preferences for short-term rationality over long-term rationality, preference for competition over cooperation, fragmentation of interests and values, fragmentation of responsibilities and authorities, and fragmentation of information and knowledge” (Pinkerton, 2007). This research has focused on the last of these biases, fragmentation of information and knowledge, as it pertains to innovation adoption and diffusion within and between agencies. Both the WCRT and IIRH have the potential to serve as common tools between agencies that would promote communication about landscape condition and encourage proactive management. The range managers interviewed generally feel innovation is difficult due to constraints of inflexible funding streams and one-size-fits-all agency policy. However, at least one respondent saw hope

that those policies could be changed if a few managers could implement the innovation and show success as a result: *“We aren’t going to go that direction about being a little more proactive about considering climatic conditions to help guide restoration until we have something that can help us. Our policies are going to lock us in, but maybe this [WCRT] could help inform changes in our policy as well if it’s successful.”* However, this creates a paradox whereby the WCRT’s adoptability may be dependent on institutional change, but that change is less likely to occur if the innovation is not adopted.

## **Implications**

By examining the characteristics of the (1) innovations, (2) individual potential adopters, (3) organization, and (4) external system in which adoption decisions are being made, we have identified barriers to adoption of two rangeland management innovations which could serve as conduits of information building and promote proactive management. While there is no panacea to these barriers, there are ways forward. Changing agency policy to allow for easier adoption of innovations requires active innovation champions at any level of the agency hierarchy. These individuals are critical to the initial identification and promotion of new methodological and technological innovations. In turn, diffusion of these innovations would then support flexibility in agency decision-making and adaptive co-management.

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CHAPTER III

COLLABORATIVE MANAGEMENT OF MULE DEER IN SOUTHEASTERN  
UTAH: AN EXAMINATION OF THE SOCIAL-ECOLOGICAL NETWORK

**Abstract**

Cross-boundary collaboration is beneficial when ecological processes cut across governance jurisdictions. Management of migratory species is a clear example of where, more often than not, ecological processes span over multiple jurisdictions, and success depends on the quality of habitats managed by different entities. Throughout the western United States, large swaths of public lands are managed by various government agencies with differing missions and objectives. Mule deer (*Odocoileus hemionus*) use habitual migration pathways to travel seasonally between summer and winter ranges. In doing so the mule deer often cross agency jurisdictional boundaries, hence requiring cross-boundary collaborations. Using social-ecological network analysis we assess potential problem areas by assessing, contemporaneously, the network of collaborations between different land and wildlife managers as well as the mule deer migration patterns in southeastern Utah, USA. We find evidence of collaboration across boundaries, but effectiveness and robustness of the network may be reduced due to a lack of information brokers. Hence, we highlight the need for redundancy in information brokers, which can absorb the impact of a potential network disturbance. While this research focuses on the social-ecological system of mule deer management in southeastern Utah, the insight into the network structure provides a precedent for analyzing similar management regimes in different contexts. Understanding the strengths and limitations of inter-agency

collaboration is a crucial facet of evaluating the potential of large-scale conservation efforts.

## **1. Introduction**

Social systems and ecological processes nearly always vary in spatial dimensions (Clark, 1987). Aligning both social and ecological systems requires collaboration of numerous stakeholders (social) across jurisdictional boundaries (ecological) and incorporation of potentially conflicting agendas (Worboys et al. 2010). Thus, cross-boundary ecological processes should direct the nature of social interactions among land managers (Folke et al., 2007). However, a spatial-scale mismatch between the management systems' boundaries and the boundaries of the larger ecosystem hinders the resilience of the overall social-ecological system (SES) (Folke et al., 2007; Guerrero et al., 2015; Knight and Landres, 1998). This is especially true of western rangelands where there are often large expanses of public land managed by a single agency adjacent to lands managed by another agency. Researchers have suggested that cross-boundary collaboration is the key to successful management at the landscape-scale (Kark et al., 2015; López-Hoffman et al., 2010). The logic behind cross-boundary collaboration is that managing an ecosystem as a whole can achieve greater outcomes than separate management of its parts. Many studies have presented the advantages of coordinating conservation efforts (Bladt et al., 2009; Gordon et al., 2013; Rodrigues and Gaston, 2002; Schoon et al., 2014). Particularly when resources cross boundaries within the same landscape it is beneficial for different actors to communicate so there is no spatial scale mismatch in management (Bodin, 2017; Crowder et al., 2006; Folke et al., 2007; Galaz et al., 2008; Guerrero et al., 2015). However, relatively few studies analyze a fully

articulated social-ecological network (Sayles et al., 2019). In this paper we examine the capacity for collaboration in management of mule deer (*Odocoileus hemionus*) and associated key habitat in southeastern Utah through social-ecological network analysis.

Migration is a behavioral strategy that enables animals to increase access to resources and decrease exposure to undesirable conditions, but often requires crossing land tenure boundaries (Baggio et al., 2011; Lendrum et al., 2013; Nicholson et al., 1997; Salau et al., 2012). Mule deer populations generally migrate between seasonal ranges because of varying environmental variables such as winter severity, midsummer drought, and forage availability (Austin, 2010; Wallmo, 1981). Taking advantage of southeastern Utah's varied topography, mule deer migrate between low elevation winter ranges and high elevation summer ranges. Mule deer, like most ungulates, follow habitual migration corridors and have high site fidelity to their seasonal ranges (Garrott et al., 1987; Sawyer et al., 2009). As such, mule deer populations are particularly vulnerable to increasing levels of anthropogenic disturbance such as habitat fragmentation (Berger, 2004).

In the United States, wildlife is managed in accordance with what has become known as the North American Model of Wildlife Conservation (Geist, 1995). The seven core components of the North American model guide wildlife conservation in the U.S. and Canada. These components are: 1) Wildlife resources are a public trust, 2) Commerce of dead wildlife is prohibited, 3) Allocation of wildlife is by law, 4) Wildlife can be killed only for a legitimate purpose, 5) Wildlife is considered an international resource, 6) Hunting and fishing is open to all citizens, 7) Best available science will inform management (Geist, 1995). The Public Trust Doctrine, dating back to Roman civil law, is the foundational basis of the first component of the Model and establishes a



trustee relationship of government to manage wildlife for the benefit of the public (Batcheller et al., 2010). As such, the state is the primary manager of the wildlife while the federal agencies manage habitat. In southeastern Utah, mule deer habitat spans some private holdings but is largely composed of federal lands managed by the Bureau of Land Management (BLM) and United States Forest Service (USFS) in southeastern Utah. These federal agencies are the primary habitat managers; with the BLM mostly managing the habitat in winter ranges and the USFS mostly managing the habitat in summer ranges. The Utah Division of Wildlife Resources (UDWR), a state agency within the Utah Department of Natural Resources, is charged with managing wildlife (Matthews, 1986). This situation, representative of the western U.S., creates a management mosaic where numerous agencies and other stakeholders are responsible for managing the same mule deer populations or their associated habitats. Thus, this study has applicability beyond the region as it is a representative case of complex institutional arrangements to manage ecological flows.

Given the cross-boundary nature of species migration, fragmentation of agency mandates that affect mule deer populations, and resulting importance of cross-boundary collaborations, here we employ social-ecological network analysis in order to determine constraints and opportunities for inter-agency collaboration. In recent years social-ecological network analysis has been increasingly employed successfully to analyze and assess potential mismatches and issues arising in managing ecological processes and flows that span multiple socio-political and economic stakeholders as well as jurisdictions (Bodin, 2017; Kininmonth et al., 2015; Mbaru and Barnes, 2017; Sayles and Baggio, 2017a, 2017b; Treml et al., 2015).

## **2. Methods**

### *2.1. Research Approach*

This study used mixed methods to evaluate collaboration in mule deer habitat management. Using qualitative thematic analysis and network analysis, we investigate 1) whether mule deer, a migrating species, in southeastern Utah are co-managed between their winter and summer ranges and 2) what barriers, if any, exist, to successful cross-boundary collaboration of mule deer habitat.

### *2.2. Study Area: Southeastern Utah*

The land surrounding and encompassing the La Sal and Abajo mountains were used to study collaborative management of lands used by mule deer herds. This study area includes most of San Juan County and the southern portion of Grand County, Utah. Southeastern Utah was selected for study because global positioning system (GPS) radio-collar data has given managers detailed information on the location and extent of mule deer habitats. Furthermore, the Colorado River, which forms a natural barrier to mule deer to the west and north, creates a partial boundary in defining the social-ecological network (Fig. 3.1).

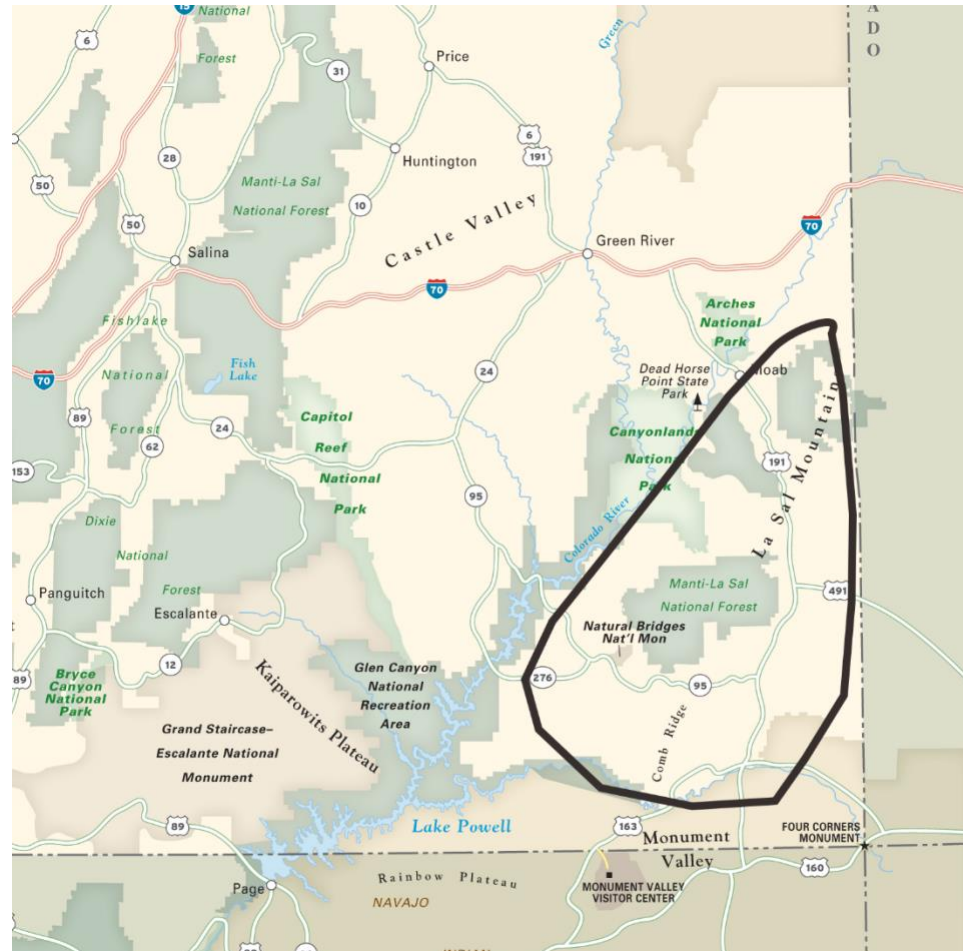


Figure 3.1. Approximate study area boundaries

### 2.3. Social-ecological Network Analysis

To form a social-ecological network the lead researcher identified: connections, or edges, between land managers (S-S edges); which land managers are responsible for each identified summer or winter range (S-E edges); and how the ranges are connected via mule deer migration (E-E edges). In other words, following Sayles et al. (2019), we generate a fully articulated social-ecological network. The E-E edges represent ecological connectivity determined by key informant reporting of GPS collar data in July 2017 that identified summer and winter ranges utilized by the bulk of southeastern Utah mule deer

and their movement between these ranges (BLMa 2015; BLMb 2014). The polygons were then digitized using ArcGIS. These maps, identifying summer and winter ranges and the migration pathways between these ranges, constitute the ecological network. The S-S and S-E edges were determined via semi-structured interviews with land/wildlife managers in southeastern Utah. In order to investigate the potential issues above, we focused on asking specific questions to agency staff responsible for managing mule deer and/or associated habitat: **1)** Do you view your agency and/or regional field office collaborates with other agencies (USFS, NPS, UDWR, etc.) when it comes to mule deer management? **2)** If so, what agencies and how do you work with them to address problems or concerns with mule deer migrations and effects on vegetation? **3)** Are there individuals within these agencies you specifically work with when it comes to managing mule deer habitat? We chose a semi-structured interview methodology so that new questions could emerge and develop from the three main questions. The interview protocol was reviewed and approved by the Institutional Review Board at Utah State University as protocol #8630.

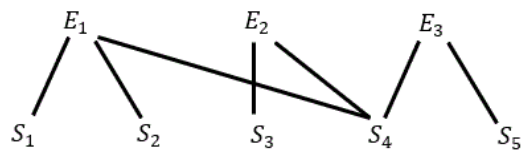
In July-August 2017, the lead author communicated with 12 individuals responsible for managing mule deer or mule deer-utilized habitat. These individuals were affiliated with the Utah Division of Wildlife Resources (UDWR), one Cooperative Wildlife Management Unit (CWMU), Utah Department of Natural Resources – Watershed Restoration Initiative (DNR-WRI), Bureau of Land Management (BLM), United States Forest Service (USFS), and National Park Service (NPS). The CWMU program through UDWR provides an incentive for private landowners to work together in managing for wildlife habitat on their land. WRI is a program separate from UDWR

but their mission is to facilitate vegetation management projects that improve vital habitat for wildlife. Six of the interviews were conducted in person. Four of the interviewees were not available in person during the study period so they were interviewed over the phone. Two of the interviewees preferred to email their responses to the questions posed. The 10 interviews conducted in person or on the telephone were audio-recorded with consent of the participants and transcribed for coding. This network represents those with authority to make changes on the landscape. Maintaining a relatively small study area and restricting eligibility to those with the authority to make changes on the landscape allowed us to focus on interviewing a significant portion of the study population, ensuring we'd reach data saturation. However, the researchers acknowledge there are likely other external individuals influencing management that were not incorporated into this study because of the boundary conditions we defined for the network so that saturation would be reached. Thematic analysis was used to assess the interviewees' collaboration in managing mule deer or their habitats. Thematic analysis is a common qualitative methodology that uses induction to systemically elucidate and explore emerging themes in the data (Braun and Clarke, 2013). Using thematic analysis, the researcher was better able to understand the broader context of collaboration in managing mule deer habitat.

The social network matrix was created using interviewees' professed collaboration connections to other interviewees and individuals outside of the study. S-S edges were assumed to be bidirectional if either individual reported the collaboration. The social-ecological network matrix was established by 1) showing the summer and winter range map to the land manager and asking which lands they are responsible for

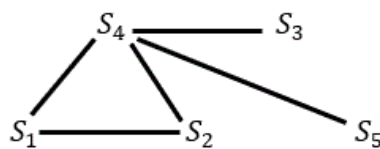
managing, or 2) defining their connection based on the jurisdiction for that particular range. In using method 1 for determining social-ecological connectivity, the land managers' responses always aligned with the ranges they would have been assigned using method 2. The ecological network matrix represents migration between key mule deer habitats.

For comparison purposes, the S-E and E-E matrices were converted so that all three layers of the social-ecological network would be represented only in terms of social actors. This conversion allowed for the network to be represented as a multiplex network, in which the nodes remain the same between layers and the edges of each layer represent different relationships. To create this multiplex network the bipartite S-E matrix and unipartite E-E matrix were projected to match the unipartite S-S matrix. An example of a bipartite social-ecological network would be:



Where  $E_x$  = Ecological node,  $S_x$  = Social node

To represent the above example using only social nodes, we converted the data to a unipartite network in which edges were created between individuals managing the same ecological node. This conversion to the unipartite 'shared jurisdiction' network yields the following network:



The above unipartite projection represents shared jurisdiction; actors are considered ‘connected’ if they are responsible for managing the same winter or summer range. A second unipartite projection of the social-ecological network was used to represent ‘ecological flows’; actors responsible for ecologically connected ranges. Using these two projected layers and the social network layer, we effectively create a multiplex network in which each node represents an individual and whose edges represent either a social collaboration, a shared jurisdiction, or an ecological flow. Transforming the network into a multiplex network allows us to assess the relative importance of specific nodes for the overall connectivity of the social-ecological network as well as, potentially, how the overall robustness of the social-ecological network may be influenced by specific disturbances affecting the network either due to changes in collaborations, changes in migration, or both (Baggio et al. 2016, Baggio and Hillis 2018, Bodin et al. 2019, Hamilton et al. 2019, Sayles et al. 2019). Ideally, we would have constructed a multilevel exponential random graph model to obtain a construal of collaboration across connected ranges in this social-ecological network. However, given the sparsity of the network, exponential random graph model methods were not able to be used. In real world networks, such as the mule deer management multiplex network, not all systems are composed of the requisite number of nodes necessary for specific analysis methods. As such, we devised a method that would analyze problems of interest within our network. We calculate the following five metrics in order to assess the relative importance of specific nodes within the social-ecological network: z-score, participation coefficient, brokerage, betweenness centrality, and degree centrality.

### 2.3.1. Universal actor roles

The two projected layers and social network layer were compared to determine land managers' activity levels within the social-ecological system. To assess such actors' roles, we calculated the participation coefficient and z-score for each node.

The z-score is a measure of how well connected a node is in one layer. If  $K_i$  is the number of links of node  $i$  to other nodes in its layer  $S_i$ ,  $\bar{K}_{S_i}$  is the average of  $K$  over all the nodes in  $S_i$  and  $\sigma_{K_{S_i}}$  is the standard deviation of  $K$  in  $S_i$ , then

$$Z^i = \frac{K_i - \bar{K}_{S_i}}{\sigma_{K_{S_i}}}$$

is the z-score.

However, the degree of connection between one node and other layers must also be calculated to determine individuals' roles within the entire SES. For example, two nodes with the same z-score will probably play different roles if one of them is connected to several nodes in one layer and not others. The participation coefficient is a measure of the distribution of edges between layers. The participation coefficient  $P_i$  of node  $i$  is defined as:

$$P_i = 1 - \sum_{s=1}^{N_M} \left( \frac{K_{is}}{K_i} \right)^2$$

where  $K_{is}$  is the number of links of node  $i$  to nodes in layer  $s$ , and  $K_i$  is the overlapping degree of node  $i$ . Therefore, the closer the participation coefficient to one, the more uniformly distributed the links are among the layers. If the participation coefficient is zero, all links are within one layer.



Comparing the participation coefficient and z-score measures of each social actor determines how well individuals are interacting in all three layers of the multiplex network, which creates a graph of generalizable actors' roles in the social-ecological network (Friesen et al., 2019; Guimerà and Nunes Amaral, 2005; Nicosia and Latora, 2015).

### 2.3.2. *Brokerage*

Brokerage was calculated to examine which individuals serve as information brokers. Gould and Fernandez (1989) define brokerage as “any relation involving three actors, two of whom are the actual parties to the transaction and one of whom is the intermediary or broker.” Based on the role of the three actors, the broker serves as one of five roles: liaison, coordinator, consultant, gatekeeper, and representative (Fig. 3.2). Brokerage is measured as the number of times in which a node serves as an intermediary/broker in each of these five roles.

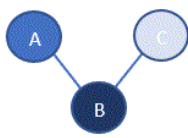
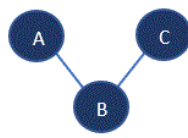
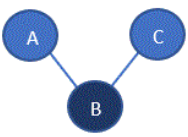
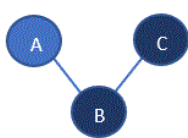
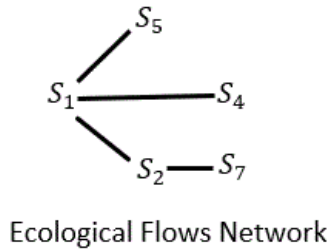
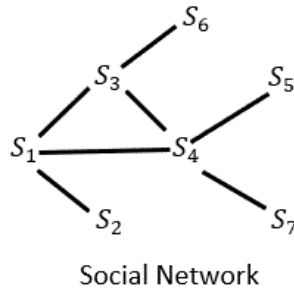
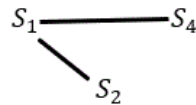
	<p><b>Liaison:</b> Actor B connects to A and C without being part of either A's or C's agency.</p>
	<p><b>Coordinator:</b> Actor B coordinates the flow of information between A and C. A, B, and C belong to the same agency.</p>
	<p><b>Consultant:</b> Actor B facilitates the flow of information in A and C's agency, without belonging to that agency.</p>
	<p><b>Gatekeeper/Representative:</b> Actor B either controls how information from its agency (C) is transmitted to actors outside its agency (A) or how information from another agency (A) is transmitted to those in its agency (C).</p>

Figure 3.2. Brokerage roles

Because edges are undirected in this study, we could not distinguish between the ‘representative’ and ‘gatekeeper’ roles so only four roles were evaluated. Thus, brokerage is a measure of how many times each actor serves in each of these four roles. Because we are interested in brokerage between actors on connected ecological nodes, the matrix we used for brokerage calculations was the social network matrix minus edges absent from the unipartite projection of ecological flows. For example, if we have the following social network and ecological flow networks:



The network of collaboration on ecological flows would be:



Thus, brokerage was only calculated for individuals that A) collaborate and B) work on connected ecological nodes. Knowing whether an actor is a liaison, coordinator, consultant, or gatekeeper/representative helps us understand which individuals the social-ecological system relies on. In turn, knowing which individuals are key can help elucidate opportunities for creating a more robust social-ecological system.

#### 2.3.4. Betweenness Centrality

Betweenness centrality was calculated for each of the multiplex layers, social network and two unipartite projections, separately. Betweenness centrality is a measure of how often a given node falls along the shortest path between two other nodes and is an indicator of a node's importance in a network based on the flow of information (Freeman,

1978). Unlike brokerage, betweenness centrality does not account for nodes' agency membership. The formula for betweenness centrality for node  $j$  is given by:

$$b_j = \sum_{i < k} \frac{g_{ijk}}{g_{ik}}$$

where  $g_{ijk}$  is the number of geodesic paths connecting nodes  $i$  and  $k$  through  $j$ , and  $g_{ik}$  is the total number of geodesic paths connecting nodes  $i$  and  $k$ . To normalize the betweenness measures between 0 and 1, scaled by the highest value within each network, we adjusted the betweenness centrality using the following equation:

$$normal(b_j) = \frac{b_j - \min(b)}{\max(b) - \min(b)}$$

where  $b_j$  is the betweenness centrality of a node  $j$  prior to normalization. Betweenness centrality values closer to 1 mean the node is often along the shortest path between two individuals and values closer to 0 mean the node is infrequently the shortest path between two individuals. Individuals that have high betweenness centrality can serve as a bridge for information flow or potentially take advantage of their structural position by restricting access to information (Burt, 2017). Alternatively, individuals with high betweenness centrality can become fatigued with transferring information across the network. In the context of mule deer management, identifying individuals with high betweenness centrality in the social network, shared jurisdiction network, and ecological flows network helps us determine who is potentially A) facilitating communication across the network and B) overburdened with synthesizing this information.

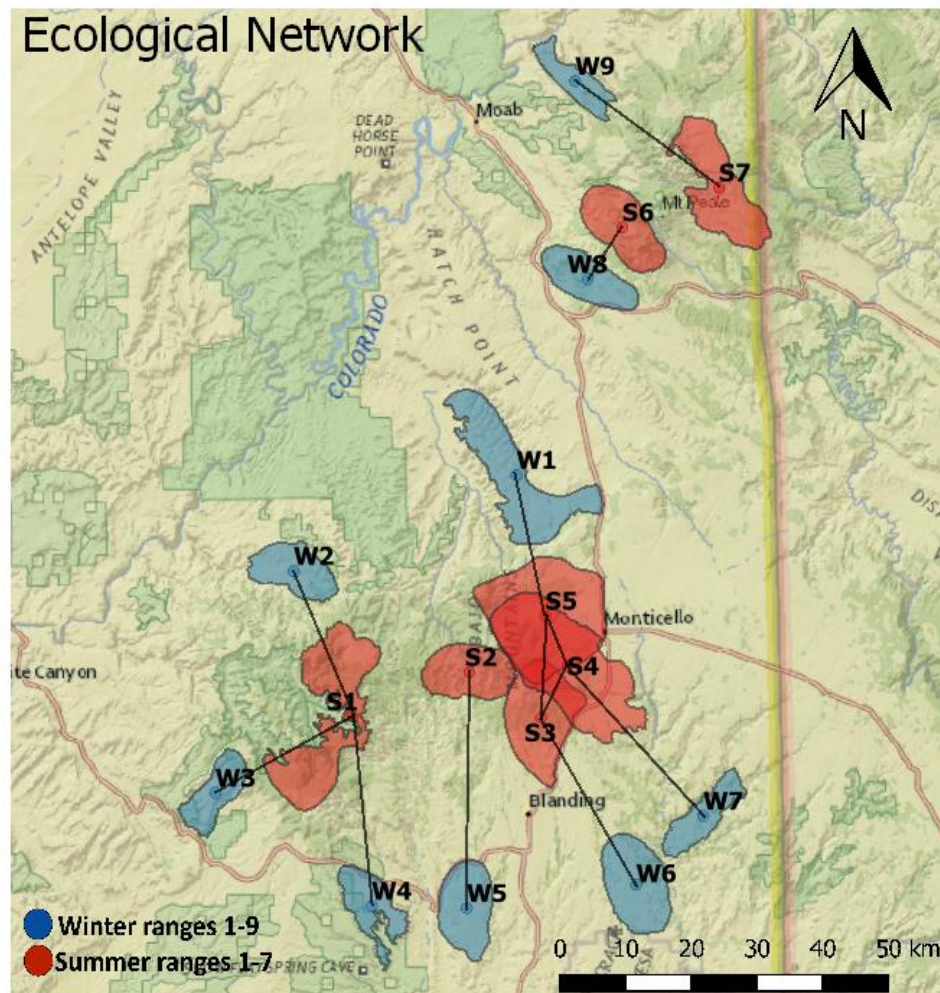
### 2.3.5. Degree

Degree centrality is the total number of edges a node has in a given network. Because a node's degree centrality can be measured without information about the full network in which the node resides, degree does not provide positional information. However, degree can be seen as a measure of a node's exposure to information. Like betweenness centrality, degree centrality does not distinguish between which agency an individual belongs to. Degree centrality was calculated on the A) social network and B) the social network matrix minus edges absent from the unipartite projection of ecological flows. In the context of mule deer management, A) provides information on how many partners a focal social node collaborates with and B) displays how many partners a focal social node collaborates with on ecologically connected nodes.

## 3. Results

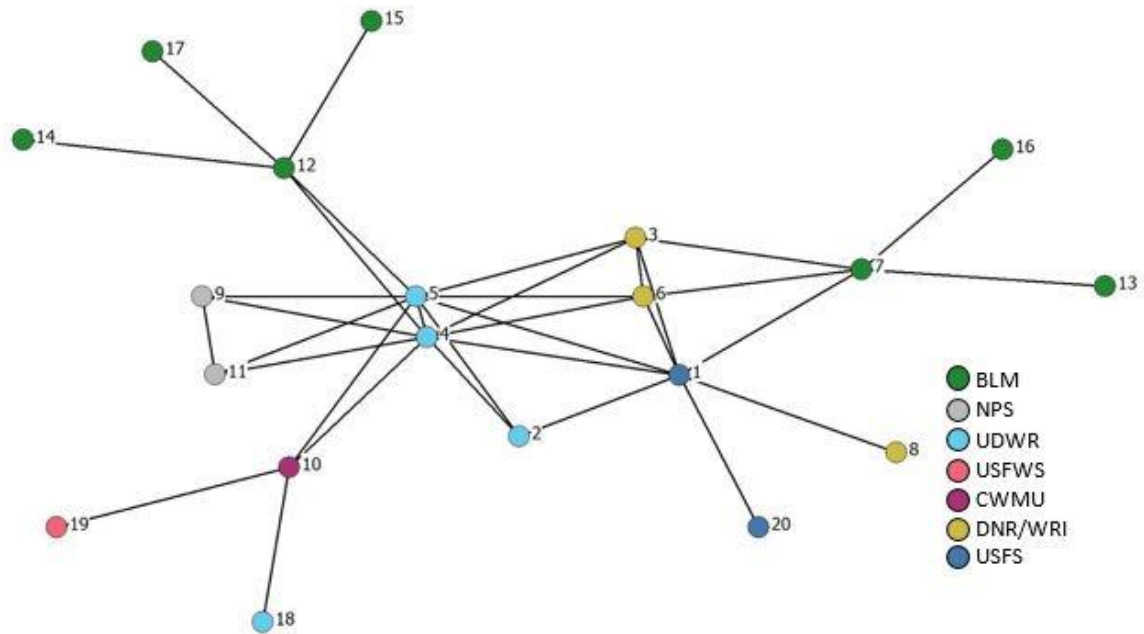
### 3.1. Social-Ecological Network Analysis

Using a key informant, the researcher was able to map the bulk of the summer and winter mule deer ranges and movement between these ranges. An ecological network was created where the nodes are individual ranges, summer or winter, and the edges between ranges were determined by presence or absence of migration (Fig. 3.3). There were nine winter ranges and seven summer ranges in the study area. This network was fairly sparse because of the nature of mule deer migration patterns; for example, there was no migration between winter ranges and only one area where 3 summer ranges overlapped.



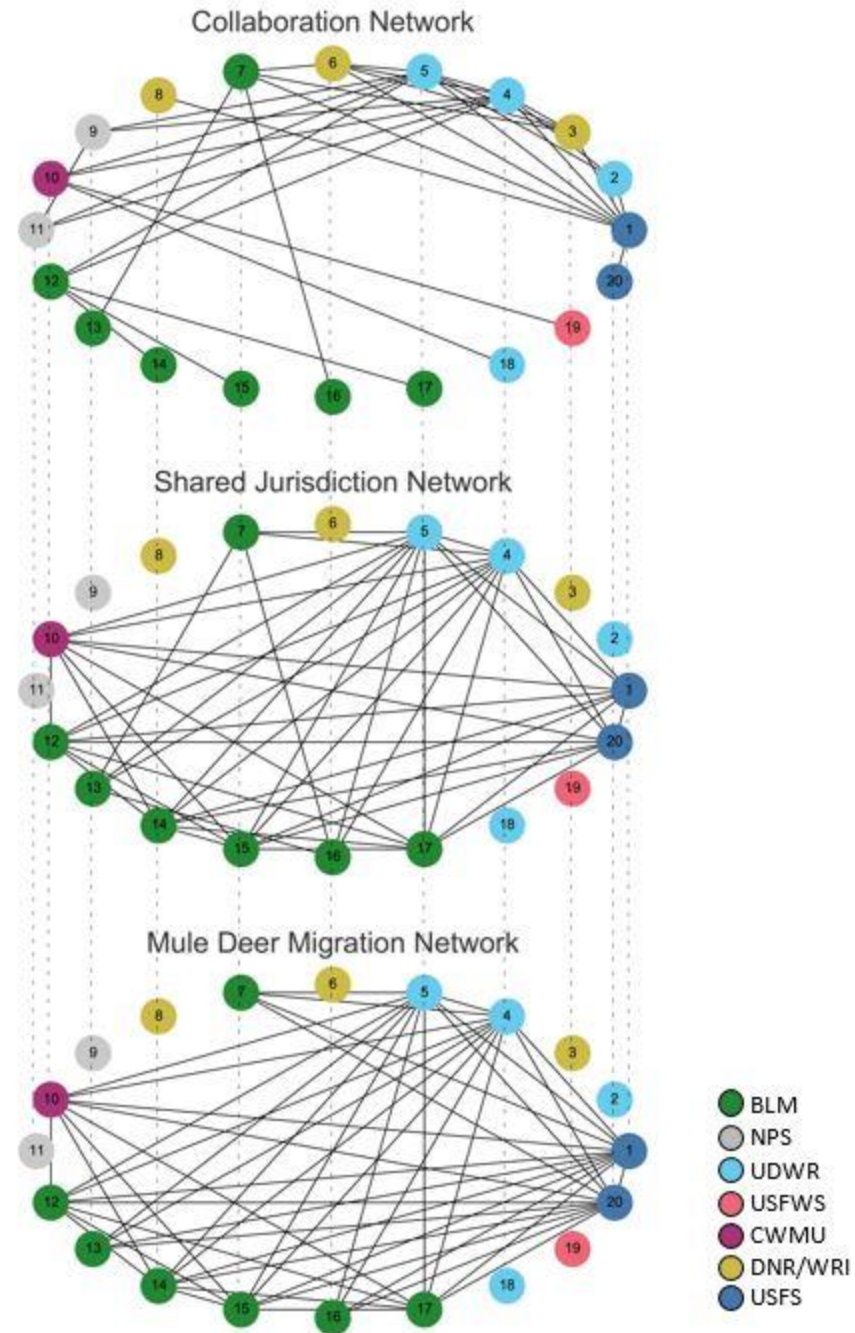
*Figure 3.3.* Mule deer migration pathways (black) between winter (blue) and summer (red) ranges in Southeastern Utah, La Sal range (upper right) and Abajo range (low center). W=Winter, S=Summer, numbers 1-9 are used as identifiers for individual ranges.

To understand how land and wildlife managers collaborate in managing mule deer and associated habitats, a social network of primarily agency employees was created based on their professed collaborative connections gathered during interviews (Fig. 4.4).



*Figure 3.4.* Perceived collaborative connections between individuals in the mule deer management network. Edges, connections between land managers, are undirected. Nodes are individuals, colored by agency membership. Graphic was created using NetDraw software (Borgatti, 2002). BLM = Bureau of Land Management, NPS = National Park Service, UDWR = Utah Division of Wildlife Resources, USFWS = U.S. Fish & Wildlife Service, CWMU = Cooperative Wildlife Management Unit, DNR/WRI = Department of Natural Resources / Watershed Restoration Initiative, USFS = United States Forest Service.

The social and ecological networks (Figs. 3 and 4), in combination with the S-E network based on what managers (social nodes) were responsible for which ranges (ecological nodes), formed the social-ecological network. Conversion of the S-E and E-E layers to unipartite projections representing ‘shared jurisdiction’ and ‘ecological flows / mule deer migration’ networks, respectively, formed the multiplex network used for analysis (Fig. 3.5).



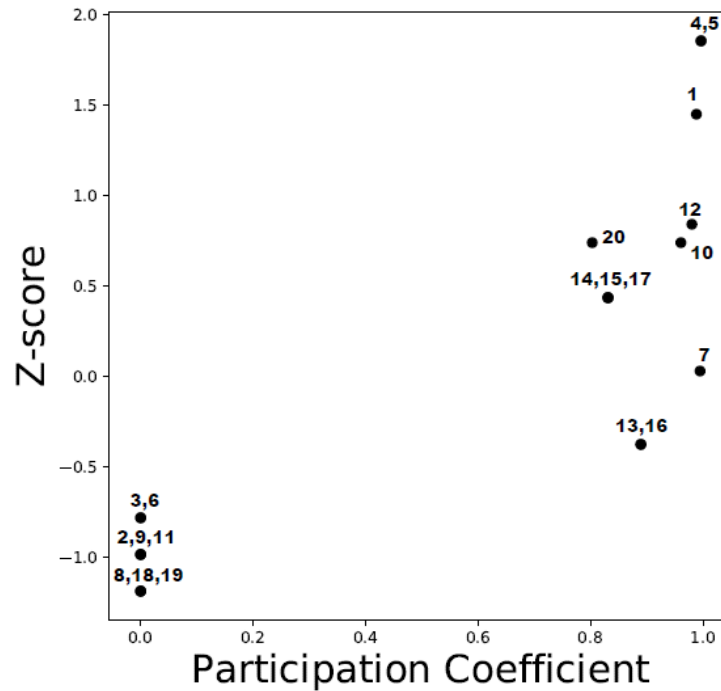
*Figure 3.5.* Social-ecological multiplex network of mule deer management. Collaboration Network = social network, Shared Jurisdiction network = unipartite projection of S-E network, Mule deer Migration = unipartite projection of E-E network (ecological flows). Node labels are identifiers for individuals.



To determine whether relevant collaborations exist for connected ranges, the researcher determined (1) social actors' activity levels within the social-ecological system using participation co-efficient and z-score measures, (2) brokerage measures for ecologically connected collaborators, (3) betweenness centrality measures for actors within each of the multiplex layers, and (4) degree centrality measures for all social actors and the subset that are ecologically connected collaborators.

### *3.1.1. Universal actor roles*

To determine universal roles of actors we adapted methodology from past studies (Nicosia and Latora 2015, Guimerà and Amaral 2005, Friesen et al. 2019). Using the transformed multiplex network in which each node represents an individual and whose edges represent either a social collaboration, a shared jurisdiction, or an ecological flow, we calculated the participation coefficient ( $P$ ) and z-score ( $z$ ). Plotting the  $zP$  parameter space, we identify actors' roles within the multiplex network (Fig. 3.6).

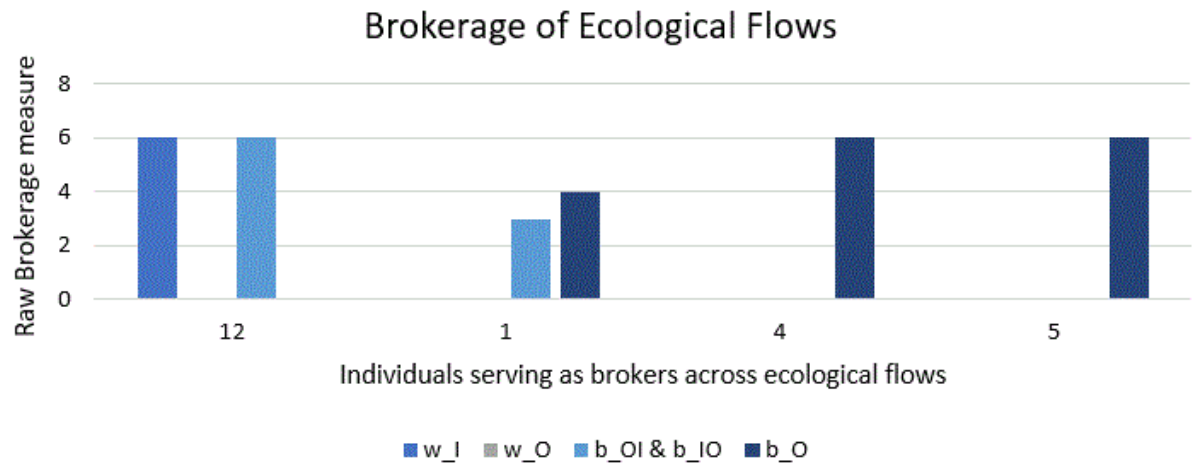


*Figure 3.6.* Generalizable actors' roles in the SE network. Numbers 1-20 are social actors within the SES.

We identified three clusters of nodes that we determine to be local, regional, and globally focused nodes in the context of the mule deer management SES. Local nodes are mainly related to one layer of the multiplex network and are also peripheral (low  $z$  and low  $P$ ). Regional nodes have few edges overall but distribute those edges across layers (low  $z$ , high  $P$ ). Global nodes are central overall and participate in all layers evenly (high  $z$  and high  $P$ ). Individuals 1, 4, and 5 were globally focused nodes. Individuals 7, 10, 12, 13, 14, 15, 16, 17, and 20 were regionally focused nodes. Individuals 2, 3, 6, 8, 9, 11, 18, and 19 were locally focused nodes.

### 3.1.2. Brokerage

The brokerage score for a given social actor, with respect to a given role, is the number of ordered pairs having the appropriate group membership(s) brokered by that social actor. Brokerage was only calculated for individuals that collaborate on connected ecological nodes (Fig. 3.7).

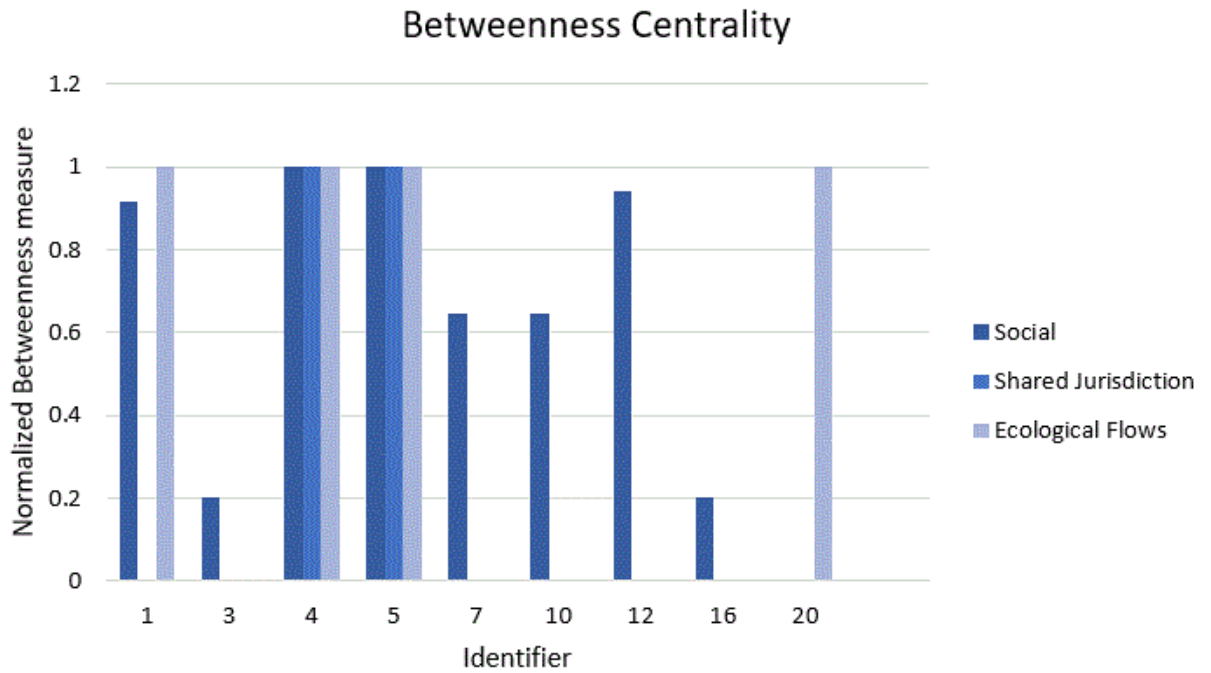


*Figure 3.7.* Brokerage measures for individuals collaborating on ecologically connected nodes. w\_I = Coordinator, w\_O = Consultant, b\_IO = Representative, b\_OI = Gatekeeper, b\_O = Liaison. 1,4,5, and 12 are social actors.

Individual 1 works for the USFS and acts as both a representative/gatekeeper and a liaison. Individuals 4 and 5 work for the UDWR and act as liaisons. Individual 12 works for the BLM and acts as both a coordinator and representative/gatekeeper.

### 3.1.3. Betweenness Centrality

Normalized betweenness centrality measures were calculated for each of the multiplex layers: social network, unipartite projection of shared jurisdiction, and unipartite projection of ecological flows (Fig. 3.8).



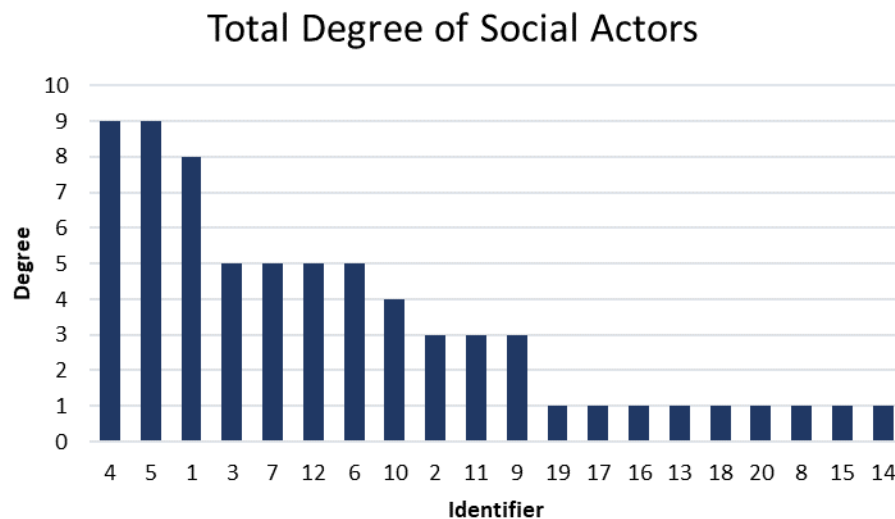
*Figure 3.8.* Normalized betweenness centrality measures across all three layers of the multiplex network.

In the social network, a total of eight individuals had a betweenness centrality measure with Individuals 1, 4, 5, and 12 having the highest betweenness centrality scores in the social network. Individuals 4 and 5 had a betweenness centrality score of 1. Individual 12 had a betweenness centrality score of 0.9415 and Individual 1 had a score of 0.9168. In the shared jurisdiction network, individuals 4 and 5 each had a betweenness centrality score of 1 with all other individuals having a betweenness centrality of 0. In the ecological flows network, Individuals 1, 4, 5, and 20 all had a betweenness centrality of 1 with all other individuals having a betweenness centrality of 0.

#### *3.1.4. Degree*

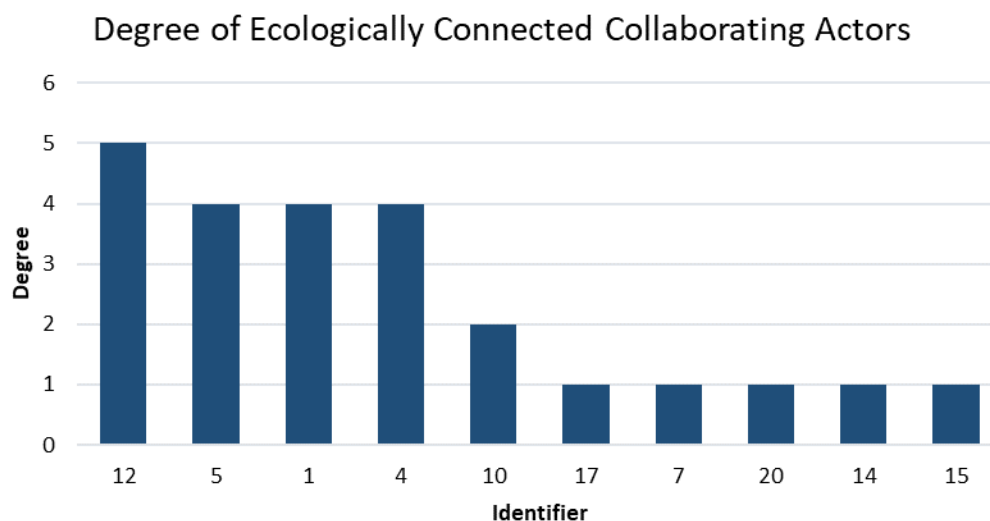
Degree centrality was calculated for the A) social network and B) network of ecologically connected collaborating actors. By the definition of the inclusion

requirements for the study, every actor in the social network (A) had a degree centrality score of at least 1; however, the distribution of degree is largely varied (Fig. 3.9).



*Figure 3.9.* Degree of actors in the social network. The x-axis ‘identifier’ represents individuals within agencies.

Not every social actor collaborated on ecologically connected nodes. As such, only one half of the actors are represented in the network of ecologically connected collaborating actors (B) (Fig. 3.10). Notably, in network B Individual 12 has the highest degree (5) with Individuals 1, 4, and 5 following with a degree of 4.



*Figure 3.10.* Degree of actors collaborating on connected ecological nodes. The x-axis 'identifier' represents individuals within agencies.

#### 4. Discussion

The state of collaboration in managing connected mule deer habitat is complex, and interviewee's responses reflected this. While social network analysis helps quantify connections, the thematic analysis of interview transcripts provided a more nuanced understanding of the complexity of cross-boundary mule deer management. There was general agreement that managing mule deer required landscape-scale effort. As one Utah farmer within the study area stated, *"You need the whole county to truly affect the deer herd. You need the whole thing to make it work."* However, interviewees' perception of the extent of inter-agency mule deer collaboration varied. Several respondents echoed the thoughts of this Utah BLM employee: *"The interface between us and the USFS is mainly doing projects adjacent to one another, but they don't necessarily mesh across the agency line."* However, another Utah BLM employee more optimistically stated that

*“We are not instinctively saying, ‘Here’s your project. Here’s my project.’ We are trying to blend together.”*

There was some indication that there was more collaboration in mule deer management because of the perceived importance of mule deer to the region. One Utah BLM employee mentioned that *“there’s definitely sharing of information and ideas across the fields, especially when you are dealing with something like mule deer.”* That is not to say that constraints to collaboration were not mentioned by interviewees. That very same interviewee also acknowledged that *“sometimes we get stuck in our own little offices and it’s hard to reach out...It is definitely more difficult to reach across state lines because there is only so much time in a day.”* This is reflected in the social-ecological network because there was a cohesive collaborative network but it was mediated by relatively few individuals. A factor that the network analysis cannot detect is stakeholder hypotheses as to why more collaboration isn’t occurring. For instance, differences in personality were frequently brought up as a major constraint to collaboration. A local farmer stated that *“people are the hardest part. It’s not the unit or the deer or other animals. It’s people; probably like most things are.”*

While collaboration between some entities can prove difficult, key individuals and programs are acting as intermediaries, filling essential roles that wouldn’t be occupied otherwise. The analysis of the social-ecological network revealed key social actors as defined by participation coefficient and z-score, brokerage measures, normalized betweenness centrality measures, and degree. We identified two individuals, 4 and 5, employees of UDWR, as especially important to the mule deer management social-ecological system. Individuals 1 and 12, employees of the USFS and BLM

respectively, also occupied important roles in the network. Individuals 1, 4, and 5 were determined to be global actors through analysis of their participation coefficient and z-score. However, individual 12 was a regional actor, meaning they had relatively fewer collaborations than 1, 4, and 5 but those connections were also evenly distributed across layers of the multiplex network. Individuals 4 and 5 had the highest normalized betweenness centrality measures in the social network (1), meaning they are both very important for connecting other actors; however, it does not account for what ranges those actors work on. Individual 12 had the second highest betweenness centrality in the social network (0.9415) and Individual 1 had the third highest score (0.9168). Individuals 4 and 5 and were the only individuals with betweenness centrality in the network of shared jurisdictions (1), meaning they have the capacity to coordinate management efforts on single ranges. This finding is probably a result of Individual 4 and 5's agency mandate to manage the state's wildlife regardless of whether the land is managed by the USFS, BLM, private entities, etc. Individuals 1, 4, 5, and 20 had a betweenness centrality of 1 in the network of ecological flows, meaning these individuals have the capacity to connect collaborators across ecologically connected ranges. However, neither the network of shared jurisdiction or ecological flows includes information about which individuals are connected through collaborative efforts; thus, we can only make assumptions about their capacity to serve as information conduits. Interestingly, Individual 20 had a degree score of 1 in both the social network and network of ecologically connected collaborators; thus, he/she is likely not connecting collaborators across ecologically connected ranges despite the opportunity to do so.



To know more about what individuals were collaborating on connected ranges we calculated brokerage measures for the network of individuals collaborating on ecologically connected ranges. Individuals 1, 4, 5, and 12 were the only brokers in the social-ecological system. Individuals 4 and 5 served as liaisons, brokers of information across two different entities, in five instances. UDWR, the employer of Individuals 4 and 5, was often brought up as a key intermediary in collaborative efforts. Individuals from within UDWR were frequently described as the primary contact for mule deer habitat management collaboration or any questions concerning mule deer populations. A Utah NPS employee observed that *“we really work with the state DWR. They are the only people that know how many deer we might have. We certainly don’t.”* Similarly, a Utah BLM employee stated that they *“work very closely with the division on habitat projects. Our collaboration is really good. Anything that UDWR comes to me with that is trying to improve deer winter range and other habitats, I do my best to facilitate the whole process that we need to go through.”* The only other individual in the network that served as a liaison was Individual 1, who acted as a liaison four times in the network. This individual also served as a representative/gatekeeper, meaning that he/she acted as the contact person for mule deer management information flowing in or out of his/her agency. Individual 12 also served as a representative/gatekeeper but did so six times within the network. Individual 12 served as a coordinator six times, mediating collaborations between two others within his/her own agency. However, having four individuals broker the relationships in this social-ecological system can present constraints, such as A) overburdening these key individuals and B) network vulnerability to vacancies.

Overall, individuals 1, 4, and 5 were involved in more collaborations (degree centrality) than the other 17 social actors, with Individuals 4 and 5 having 9 connections and Individual 1 having 8. However, degree centrality within the social network does not give information on whether collaborations are occurring on ecologically connected ranges (nodes). Examining just the network of individuals collaborating on connected ecological nodes Individual 12 was the most active with a degree of 5. Individuals 1, 4, and 5 were the only other social actors with a measure in this network and had a degree centrality of 4.

While Individuals 1, 4, 5, and 12 frequently served as intermediaries for management of mule deer or associated habitats, it was largely the Watershed Restoration Initiative (WRI) that facilitated and organized this collaboration. The Watershed Restoration Initiative (WRI) is a Utah partnership-based program, sponsored by the Utah Partners for Conservation and Development, aiming to improve high priority watersheds throughout the state. The WRI is a bottom-up initiative where project planning, review, and ranking occur at a local level. As one Utah BLM employee put it, *“That’s [WRI] mainly where we interface with other folks. That’s where we come together and plan projects that cross boundaries.”* This opinion was shared with many of the interviewees. A USFS employee mentioned how *“the WRI process makes it really easy to do cross-boundary collaboration”* and that *“having more eyes look at proposals makes sure they are good projects.”* From the interviews it was apparent that the WRI served as an organizing entity, bringing different agencies together to talk about potential projects. This is a finding that wasn’t clear from the social-ecological network and an instance where more nuanced understanding of the broader management, gleaned from interview

transcripts, was needed to have a greater sense of how collaborative relationships are being organized in this setting.

## **5. Conclusions**

Spatial mismatches between scales of management and ecological processes are present across the world (Bodin, 2017; Crowder et al., 2006; Folke et al., 2007; Galaz et al., 2008; Guerrero et al., 2015). Current jurisdictions of federal, state, and privately managed lands within the western U.S. create a management mosaic where numerous agencies and other stakeholders are responsible for managing connected ecosystems. This research followed one ecological flow, mule deer populations, in Southeastern Utah to examine how the same mule deer populations or their associated habitats are being collaboratively managed across jurisdictions. Thus, while this research is a case study it provides a representative example of complex institutional arrangements to manage ecological flows, making our findings applicable to novel contexts.

Social-ecological system connectivity in this context facilitates information flow between land managers, albeit it is difficult to draw conclusions on how that impacts mule deer and their associated habitats in reality. When we combine our social-ecological network analysis results with our more in-depth look at the overall context and nature of collaborative connections, gathered through thematic analysis of dialogue with interviewees, we can discern strengths and weaknesses of a management system aiming to collaboratively manage migrating species. This aim is important because a lack of collaboration can make it difficult to identify best management approaches when there is a shock to the social-ecological system (Knight and Landres, 1998). Quickly restoring critical ecosystem and social system processes at the landscape-scale requires managers

to identify impacts of the shock and determine best approaches for mitigating those impacts. Thus, cross-boundary collaboration assists managers' efforts to retain social-ecological system functionality when faced with system perturbations.

Overall, there was collaborative connectivity between connected mule deer populations and associated habitats that may have been driven by the perceived recreational and economic valuation of mule deer. However, the network was quite sparse and collaborations were brokered through only a handful of individuals. High network connectivity can safeguard against network disturbances (Dakos et al., 2015). When connectivity is mainly due to a few actors, the overall system can be prone to issues. For example, perturbations in the social network, e.g. funding shortages or personality clashes, or ecological network, e.g. changes in mule deer migration patterns, can destabilize the system. With four individuals acting as bridges in this social-ecological system, there may be bottlenecks of information flow and these key individuals can potentially be overburdened with conveying information across bottlenecks, taking away time from other necessary tasks (Cross and Prusak, 2002).

Furthermore, it has been argued that high levels of social network connectivity increases information-sharing and helps develop trust among stakeholders (Brondizio et al., 2009). In the context of this social-ecological network, that would require increased collaboration between managers in different agencies, rather than using an intermediary such as the UDWR to communicate. However, networks of high connectivity do have their limitations. Forming collaborations is cost intensive in terms of time and capital, so a point of diminishing returns is reached in forming collaborative connections (Bodin et al., 2006; Sayles and Baggio, 2017a). Additionally, highly connected networks can lead

to homogenization of management strategies that reduces capacity to find novel solutions, which can in turn lead to suboptimal management (Bodin and Crona, 2009; Dakos et al., 2015). Thus, the challenge is finding the balance between network connectivity and individual agency independence. On one end of this spectrum managers risk network fragmentation due to disturbances such as position vacancies, and on the other end managers face unnecessary collaborations that make management costly and time-intensive without additional ecological benefits. However, this is where an organizing entity such as the Watershed Restoration Initiative (WRI) can play an important role. Because the WRI brings together agency personnel from a variety of land management agencies to review and rank project plans, providing an opportunity for input from diverse stakeholders, it was often cited as the means for collaborative connections. Furthermore, the WRI can serve as a repository for institutional memory in the event of employee turnover that reduces the resilience of the mule deer management social-ecological system.

Evaluating large-scale conservation efforts, like that required for cross-boundary mule deer management, requires an understanding of the strengths and limitations of inter-agency collaboration. We find evidence of inter-agency collaboration for mule deer in the context of this study, but that collaborations are often mediated by a handful of individuals and one organizing entity. Given that landscape-scale conservation is needed to not just conserve a single species but to manage biodiversity more broadly, further research into how other cross-boundary ecological flows (e.g. invasive species, wildfire, etc.) are more generally being managed across the mosaic of Western public lands is required to diagnose where there are spatial mismatches across scales. We envision our

findings contributing to this broader literature and enriching understanding of cross-boundary collaboration processes more generally.

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CHAPTER IV

EFFECTS OF WILDFIRE ON COLLABORATIVE MANAGEMENT OF  
RANGELANDS: A CASE STUDY OF THE 2015 SODA FIRE

**Abstract**

In the United States almost half of rangelands are publicly owned and managed by federal and state agencies. When landscape-scale disturbances such as wildfire and non-native species invasion cross jurisdictional boundaries, multiple agencies are involved in rehabilitating the same landscape, only separated by man-made boundaries. Furthermore, as rangeland wildfires have grown in frequency and size, multi-jurisdictional ‘mega-fires’ are becoming more common. The 2015 Soda Fire burned approximately 280,000 acres of southwestern Idaho and southeastern Oregon, including parts of Owyhee County, Idaho and Malheur County, Oregon. Because rehabilitation actions immediately following a wildfire have impacts on the later recovery of the landscape, this case study focused on understanding the dynamics of cross-boundary collaboration following the Soda Fire. Using semi-structured interview methods, 24 land managers, private landowners, and decision-makers were interviewed about (1) collaborations that existed on Soda Fire lands before and after the burn, in order to understand whether new connections were forged or latent ones activated as a response to the fire, (2) how these collaborations were formed, and (3) how successful participants perceived those collaborations to be. We found that relationships established in other management contexts were activated by individuals within agencies to share funding and resources to rehabilitate the landscape. This fire’s spatial proximity to Boise, Idaho, and temporal proximity to important federal policy decisions, were often cited by

interviewees as their primary collaboration drivers. While many interviewees expressed that this was the first time such a large-scale collaborative management effort had occurred in the area, they also highlighted barriers to collaborative efforts that still exist and potential opportunities for incrementally lessening these constraints.

## **Introduction**

Rangelands in the interior western United States represent a landscape mosaic of public and private ownership with the majority being public. Seventy percent of the Great Basin is public land (Torregrosa and Devoe, 2008); thus, land managers from federal agencies such as the Bureau of Land Management and United States Forest Service, in conjunction with state agencies, are responsible for managing these public lands. However, landscape-scale disturbances such as large wildfires and non-native species invasions affect multiple jurisdictions. As such, restoration or rehabilitation post-disturbance should ideally be collaborative. Past research suggests that cross-boundary entities that are able to balance centralized control and lateral emergent cooperation are in a better position to manage crises (B. Nowell et al., 2018; Siciliano and Wukich, 2016; Wukich and Robinson, 2013).

In this study we concentrate on the problem of wildfire and post-fire rehabilitation because their impact on the landscape can be drastic and affect key supporting, regulating, provisioning, and cultural ecosystem services provided by rangelands (Havstad et al., 2007). While fire at natural intervals is a healthy and dynamic part of most ecosystems, wildfires in the Great Basin when fuel loading is high can lead to adverse consequences such as soil sterilization and hydrophobicity, accelerated runoff and erosion, and conversion of native grass-shrub communities to non-native annual

grassland dominated by invasive cheatgrass (*Bromus tectorum*) and medusahead (*Taeniatherum caput-medusa*) (D'Antonio and Vitousek 1992, Knapp 1996, Parise and Cannon 2012). Historically, wildfires varied in size and severity with a return interval of 100-150 years for large, severe fires (Pierson et al., 2011). Smaller, less intense fires had a return interval of 20-40 years (Pierson et al., 2011). However, current fire return intervals on cheatgrass dominated plant communities are now only 3 to 10 years (Brooks et al., 2004; Whisenant, 1990). Additionally, 'Mega-fires', large-scale wildfires burning 100,000 acres or more, are increasingly prevalent (Chambers and Pellant, 2008). In 2007, the Murphy Complex fire burned 652,016 acres in Idaho and Nevada. In 2012, the Long Draw Fire burned 557,648 acres in southeastern Oregon. In 2015, the Soda Fire, the fire of interest within this study, burned 279,144 acres in southwestern Idaho and southeastern Oregon. More recently, the Martin Fire burned 435,569 acres in northern Nevada in 2018.

With increased incidence of large-scale, multi-jurisdictional wildfires on rangelands and the potential ecological and economic costs resulting from suppression and rehabilitation efforts, understanding the dynamics of cross-boundary collaboration is useful for confronting the challenges posed by mega-fires. However, collaborating on restoration can be problematic when the agencies and stakeholders have diverse institutional cultures, protocols, mandates, and political realities (Bestelmeyer and Briske, 2012; Cortner and Moote, 1999; Koontz and Bodine, 2008; Wondolleck and Yaffee, 2000). Ansell, Boin, and Keller (2010) identify four administrative challenges to transboundary crisis responses: 1) coping with uncertainty, 2) providing surge capacity, 3) organizing a response, and 4) communication with the public. These challenges are



present regardless of whether the event is transboundary or more localized. However, transboundary crises call for exceptional cooperation under conditions when it's the hardest to achieve – when the authority for response is distributed across several jurisdictions (Ansell et al., 2010). In a study of wildland interface fires in the U.S. Northwest, Faas et al. (2017) found that federal land agencies served as the bridging actor, an intermediary between two or more unconnected actors, even though they were A) not the entity others anticipated seeking out and B) one of the least trusted entities within the network. Thus, having a nuanced understanding of how federal land agencies are interfacing with other stakeholders in post-fire rehabilitation efforts is an important contribution to the literature that can elucidate potential future organizational changes that would ultimately build trust.

## **Methods**

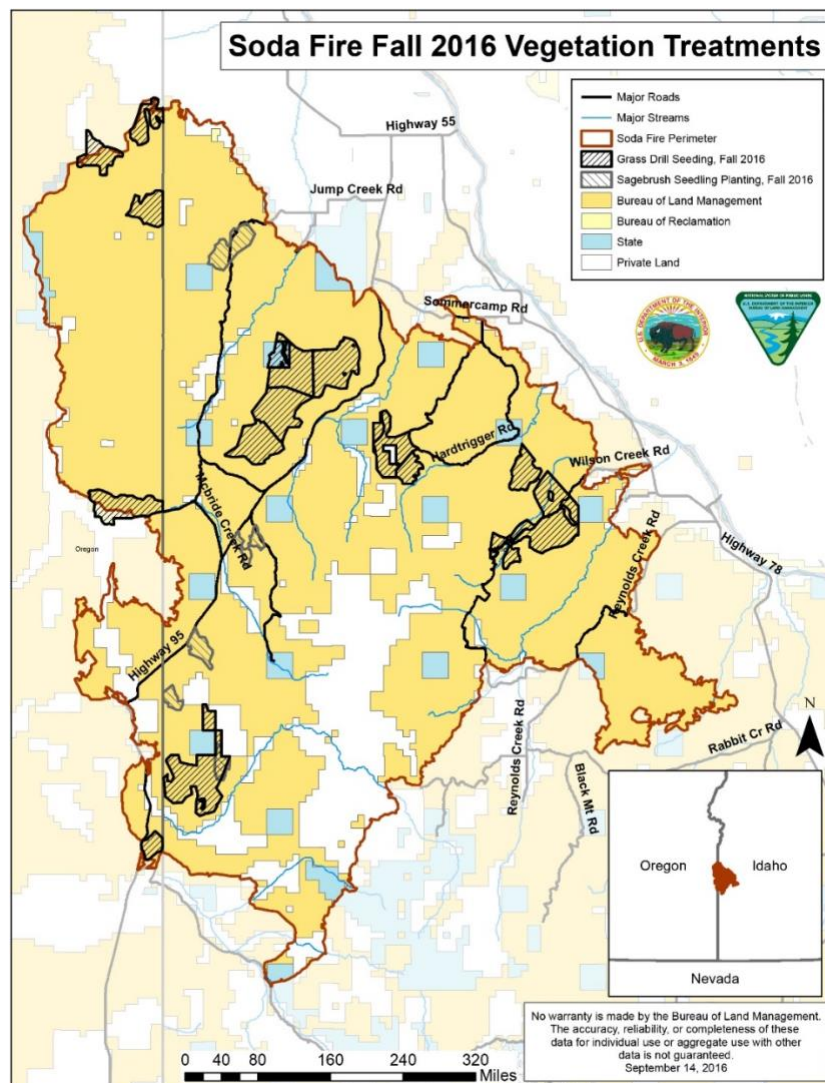
### *Research Approach*

This research is a case study focused on understanding how collaborative management efforts were altered following a large-scale wildfire that crossed two states and multiple field office jurisdictions. Using semi-structured interviews, we identify 1) collaborative efforts before, resulting from, and after the Soda Fire 2) barriers to landscape-scale collaborative management and 3) opportunities for continued and increased participation in collaborative processes.

### *Study Area*

Lands within or near the 280,000-acre burn area resulting from the 2015 Soda Fire are the focus of this research. The Soda Fire burn region was chosen because it is an example of a large-scale post-wildfire rehabilitation crossing multiple jurisdictions. These

lands include parts of Owyhee County, Idaho and Malheur County, Oregon. The burn was mainly on BLM managed lands but also included state trust lands and private inholdings. Notably, the fire impacted approximately 200,000 acres of Greater Sage-Grouse habitat, segments of 41 grazing allotments, three wild horse areas and popular recreation area (Bureau of Land Management, 2016a) (Fig. 4.1).



*Figure 4.1.* Burn perimeter of the 2015 Soda Fire, including land tenure and 2016 vegetation treatments (Bureau of Land Management, 2016b). Bureau of Land Management License CC-BY. Accessed at: <https://idfg.idaho.gov/blog/2016/09/treatments-continue-owyhee-countys-soda-fire>

*Survey & Interview Protocol*

To better understand how land managers collaborated both before and after the Soda Fire, we used snowball sampling methodology (Noy, 2008) to conduct semi-structured interviews with individuals from federal and state agencies as well as private landowners. Snowball sampling uses initial informants to nominate other participants who could potentially contribute to our study. We used an event-based sampling methodology as a boundary specification for generating post-fire response networks, building on previously developed methodological approaches used in studying previous incidents (Laumann et al., 1989; B. L. Nowell et al., 2018; Steelman et al., 2014). In other words, for incorporation into the social network, actors had to be part of the event (i.e. Soda Fire rehabilitation response). However, because we were interested in the context in which the Soda Fire rehabilitation effort occurred, our interview criteria combined the event-based sampling methodology with a positional actor characteristic sampling approach (B. L. Nowell et al., 2018) to include those who were not part of the formal institutional response to the Soda Fire but A) perceived they should have been and/or B) were involved in collaborative efforts within the proximity of the study area before and after the Soda Fire. From November 2018 – March 2019, we communicated with 24 individuals who were directly or indirectly involved in post-fire collaborative processes on the lands burned by the Soda Fire and/or pre-fire collaborative restoration efforts within the vicinity of the Soda Fire. In examining pre-fire collaborative processes, we focused on collaborations five years prior to the 2015 Soda Fire up to the date of the interview to set a temporal boundary for the study; however, collaborations prior to 2010 were considered if interviewees mentioned their significance leading up to the Soda Fire.

Individuals were interviewed from the Idaho and Oregon Bureau of Land Management (BLM), U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS), USDA – Natural Resources Conservation Service (NRCS), USDA – Agricultural Research Service (ARS), Idaho State Department of Agriculture (ISDA), Idaho Department of Lands (IDL), Idaho Fish & Game (IDFG), Idaho Governor’s Office of Species Conservation (OSC), Owyhee County, Owyhee Rangeland Fire Protection Association (RPFA), Jordan Valley Cooperative Weed Management Area (JVCWMA), The Nature Conservancy (TNC), and private landowners.

The interviews were conducted using a protocol and script but were semi-structured so that new topics could be explored as they emerged. Interviews were audio-recorded and transcribed for coding. The interview protocol was reviewed and approved by the Institutional Review Board at Utah State University as protocol #9537. Thematic analysis of interview transcripts was used to inductively discover and examine themes in the data. Thematic analysis is commonly used in qualitative research to systematically code data for patterns and extract major emergent themes (Braun and Clarke, 2013). In order to investigate collaborative management efforts before and after the Soda Fire, we asked the following: **1)** What do you believe should be the management priorities for the lands burned by the Soda Fire? **2)** How do you define successful collaboration? **3)** Using your definition of collaboration, with whom have you collaborated in the five years prior to/since the Soda Fire by year? **4)** How successful do you perceive those collaborations to be on a scale from 0 to 100? 0 = Negative experience, 100 = Extremely successful **5)** How long were those collaborations or how long do you expect those collaborations to last? **6)** Can you mention any management output or environmental outcomes, tangible or

not, resulting from collaborations you've engaged in? For the full list of questions, see Appendix G.

Mattessich et al.'s (2001) framework was used to distinguish cooperation, coordination, and collaboration. Cooperation is characterized by informal relationships in which entities function separately with no required joint planning and share information only as needed. Within a cooperative relationship, resources are separate, and thus authority and accountability also reside within each individual entity. Often cooperation is present in an as needed basis with no specific time limit. Coordination, however, usually takes place around a specific project with a mission that has at least been reviewed for compatibility by the separate entities. Coordination is characterized by partial sharing of leadership although entities maintain separate identities and assume needed roles and openly communicate frequently. Alternatively, collaboration requires a common mission with a formal division of labor centered around one or more long-term projects. In contrast to both cooperation and coordination, collaboration is characterized by dispersed leadership with equal risk shared by all entities. For the sake of clarity, we refer to cooperation, coordination, and collaboration broadly as collaboration until the discussion section, in which we more carefully dissect interviewee's relationships.

For perceived success ratings of the collaborations, we calculated the mean, median, and mode of the collaboration ratings resulting from the Soda Fire. Collaborations both before and after the Soda Fire that didn't directly relate to the fire varied in subject and participants; thus, we did not average across ratings for these collaborations.

A social network of collaborations resulting from the Soda Fire rehabilitation efforts was created for visualization purposes. In the context of this study, the nodes are agencies, organizations, or groups of individuals. The edges between nodes represent collaboration/coordination/cooperation broadly. Constructing a visual representation of the Soda Fire collaborative efforts provides a qualitative overview of the data that is investigated further through thematic analysis.

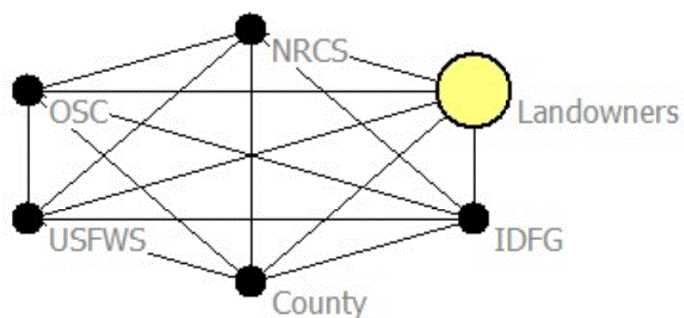
## **Results**

### *State of Collaboration*

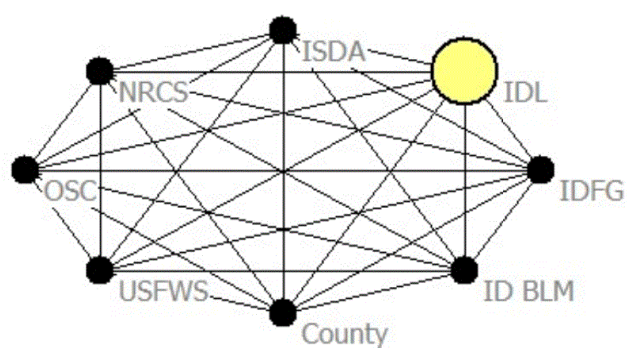
*“I was amazed at how much planning and collaboration went into [the] Soda Fire. I could just see this is a new era in management and it’s something that was really needed.” -IDFG employee*

As portrayed in the above quote, the Soda Fire rehabilitation effort was a unique effort to embody the “all hands, all lands” approach (Charnley et al., 2017) to management of resilient landscapes. In rehabilitating the lands that burned in the Soda Fire at the landscape-scale there were essentially three collaborative processes dependent on land ownership/jurisdiction: private lands, state managed lands, and federally managed lands (Fig. 4.2).

### PRIVATE LANDS



### STATE LANDS



### FEDERAL LANDS

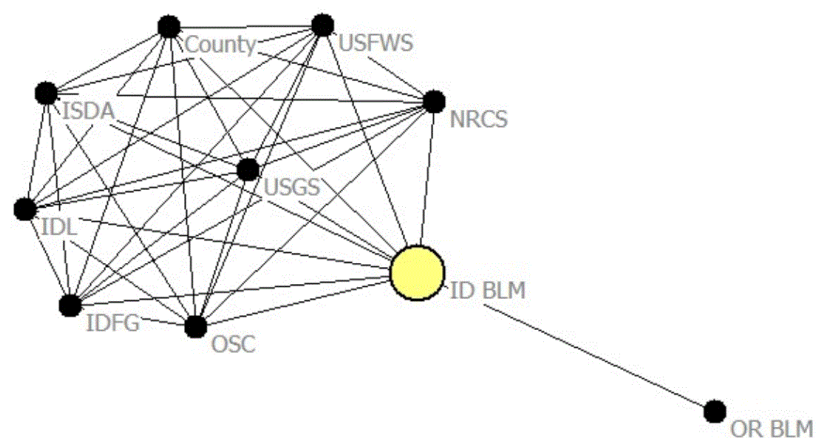


Figure 4.2. Collaborative network by land type: private, state, federal. Large yellow node signifies which entity is predominately in charge of decision-making.

In the context of the Soda Fire, the state and federal lands were effectively managed together. However, in the above figure the collaborative processes are shown separately to highlight that IDL is still ultimately in charge of decision-making on state lands. While the edges between nodes represent ‘collaboration’, the level of collaboration varied but was not quantified. As one NRCS employee explained, *“Our biggest benefit of the inter-agency collaboration is allowing us to share resources and information with each other, so we can get the most efficient and beneficial use of the funds that we have available.”* For this individual, sharing information so that NRCS would know how to best distribute funds was important; however, some agency employees described their collaboration in post-fire rehabilitation to be more defined by technical assistance. While some interviewees said their collaboration consisted of shared decision-making, more described an arms-length collaborative process, such as that explained by an ISDA employee: *“There were definitely times where the group felt like we were just being updated rather than providing input that action was taken on, but it was definitely better than what we usually get.”* This opinion was shared by an NRCS employee who stated, *“We were kind of limited on how much input we could provide on that initial restoration response, but we were informed, which was more information than all of us partners had really ever received before.”* In the quote above and the previous quote from ISDA, both individuals felt restricted but simultaneously thankful for the line of communication opened during this collaborative process.

There was a noted divide between management on the Oregon and Idaho sides of this fire. Several interviewees mentioned that post-fire rehabilitation was more a priority, socio-politically, on the Idaho side than the Oregon side. As an employee of the Oregon



BLM explained, *“I felt like there was definitely more emphasis from the Idaho side than there was on the Oregon side, so getting both sides on the same page in terms of importance and scale and how we were going to approach this was a challenge from the beginning.”* Interviewees mentioned that Oregon had its own process, and while there was collaboration in the sense of communication there was not in the sense of seamless treatment strategies across the state boundary. A USFWS employee expressed that *“the collaboration was not cross-jurisdictional from at least a state perspective. That’s not to say that what they did was better or worse. I’m just saying it’s certainly not the same.”* Some interviewees suggested the Soda Fire rehabilitation was a bigger priority in Idaho because of 1) its proximity to the state capital, Boise 2) attention from disgruntled stakeholder groups, such as some environmental groups and grazing permittees and 3) the amount of priority Greater Sage-grouse habitat that was negatively impacted.

*Impetus for Collaboration: Executive Order 3336 & Greater Sage-grouse*

On January 5, 2015, then-Secretary of the Interior, Sally Jewell, signed Executive Order 3336 which called for improved coordination in addressing rangeland wildfire and its impacts on wildlife, recreation, and economic activity. The Order explicitly mentioned conserving habitat for sagebrush-steppe dependent species such as Greater Sage-grouse. From August 10-23, 2015, the Soda Fire burned approximately 280,000 acres, of which 50,000 acres were priority habitat for Greater Sage-grouse (*Centrocercus urophasianus*). The U.S. Fish & Wildlife Service’s decision deadline on whether to list the Greater Sage-grouse as a threatened or endangered species was set for September 30, 2015, and multiple interviewees mentioned that this increased their involvement and the funding they had available. The Idaho BLM relayed that *“because of the sage-grouse potential*

*listing all the other agencies had bigger pots of money.”* One of the agencies with funding reserves for such sage grouse-related projects was the Idaho Governor’s Office of Species Conservation (OSC). An OSC employee described the Soda Fire as *“one of the big fires that happened while all this ESA and sage grouse talk was going down so we were like, ‘We need to do something.’”* The timing of the Soda Fire between that of Executive Order 3336 and the U.S. Fish & Wildlife Service’s sage-grouse listing decision deadline placed the rehabilitation process under the spotlight of federal agency administration and the greater public. As one USFWS employee stated, *“I think there was a point made somewhere along the line that the Soda Fire was going to be the pilot for that executive order.”* Certainly, Executive Order 3336 and the potential sage-grouse listing created a window of opportunity for forging new collaborative relationships in rehabilitating the Soda Fire landscape; however, for most interviewees these relationships already existed. As one employee of IDL said, *“Sage-grouse is a big thing here, so we have relationships with our federal partners and with our lessees on sage-grouse habitat. This [Soda Fire collaboration] was just an extension of those relationships.”*

#### *Repurposed Relationships*

When asked about collaborations prior to and after the Soda Fire, interviewees frequently described their collaborative projects on issues like fuel breaks, noxious weed control, and juniper removal. For instance, the Oregon BLM mentioned that *“a lot of the collaboration that started with Soda is helping us with Tri-State.”* This is a reference to the Tri-State fuel break project, a large-scale network of fuel breaks across parts of Idaho, Oregon, and Nevada. It became clear from the interviewees that collaborations resulting from the Soda Fire were products of prior collaborations that continued or revived after

the Soda Fire rehabilitation effort slowed. As the Idaho BLM put it: *“There’s never a beginning and an end to collaboration.”* Rather, it appears in this context that collaborations are driven by 1) obvious need (i.e. wildfire) and 2) agencies’ current management priorities, which often shift with administrative changes. One USGS employee explains that *“things will just kind of morph and we’ll work on the same kind of themes but in new contexts. It won’t be like a comprehensive response to a specific fire. It’s going to be more on specific control options for cheatgrass or studying the effectiveness of fuel breaks.”* What we’re referring to as ‘repurposed relationships’ are those relations that change and evolve as needs and priorities shift. An Oregon BLM employee provided an example of this when mentioning that they are *“now looking at a kind of pasture-scale targeted grazing research effort. That’s another example where collaboration that began during Soda spawned another effort of BLM’s working with our partners to address this fire issue in sagebrush steppe.”* In fact, this collaborative project using targeted grazing for fuel breaks was the only project interviewees mentioned after but not before the Soda Fire. All other collaborations interviewees brought up were present both before and after the Soda Fire. While collaborations between agencies may be fairly constant, collaborations between individuals within separate agencies have a starting point. For a couple of the interviewees, new connections were forged because of the Soda Fire collaborative efforts, as this IDFG employee exemplified: *“[X at the BLM] and I built a relationship that kind of started with Soda. His email was on the collaborative. That’s when I really met him.”* Because, ultimately, collaborations occur between individuals, not agencies, the Soda Fire collaboration provided an opportunity for individuals to start or maintain partnerships and learn from each other.

### *Learning processes*

In learning about each other, collaborators were able to garner a better understanding of agency processes other than their own. For instance, one NRCS employee mentioned, *“I think we all learned quite a bit because we didn’t know how the BLM did it before and so now it makes more sense. And so we’re hoping that the next time we will have a little better understanding of how the process works and we can actually facilitate a better partnership.”* An Oregon BLM employee also came to the conclusion that *“a lot of the collaborators had a misconception of what the BLM did or didn’t do post-fire, so I think Soda brought a lot of opportunity for those players to know the process that we go through.”* In addition, the Soda Fire provided a window of opportunity for learning about post-fire recovery. Through a unique partnership with USGS, extensive monitoring of the Soda Fire landscape is being conducted. Several interviewees mentioned how the monitoring will be beneficial in the future. For instance, an NRCS employee stated that *“what came out of this is that they monitored the entire fire, so next time there’s a big fire, there’s a baseline dataset.”* Likewise, an individual from the Oregon BLM thought that the monitoring *“is something to be really proud of ... and that’s probably where we were the most stable and had no boundaries.”* While the USGS was very involved with the rehabilitation effort, another research-based agency, the U.S. Department of Agriculture – Agricultural Research Service (ARS) had limited engagement for reasons that are not completely clear. As one ARS employee stated, *“Why the BLM has not engaged with ARS has been a question for ours for a number of years ... We produce tons of results and data that are used around the world and they should hold us up as a trophy and they just don’t. I’m not blaming any one person. It’s an*

*agency-wide mentality. It's kind of institutionalized within them."* Because ARS is part of the U.S. Department of Agriculture (USDA) and the USGS and BLM are both part of the U.S. Department of the Interior (DOI), it's possible the BLM was more readily able to form connections within the domain of the DOI. While perhaps ARS could have provided more research following the Soda Fire, there were many positive outcomes resulting from the Soda Fire collaboration that interviewees mentioned.

### *Outcomes*

When asked to quantify the perceived success of the overall Soda Fire rehabilitation collaboration, the 42% of interviewees that responded to the question were fairly consistent in their responses. On a scale from 0 to 100, with 50 being neutral, the mean, median, and mode of responses was 70 (Fig. 4.3). One individual did not provide an overall score but did so for each agency separately. This individual gave the BLM a 20 because of concerns about grazing resumption standards and gave the other collaborators on private lands a 95. The interviewee expressed concerns that cattle grazing was prohibited beyond the necessary time frame for sufficient rangeland rehabilitation, which in turn negatively impacted ranchers' livelihoods. This response was not included in the above analysis but does provide an alternative perspective.

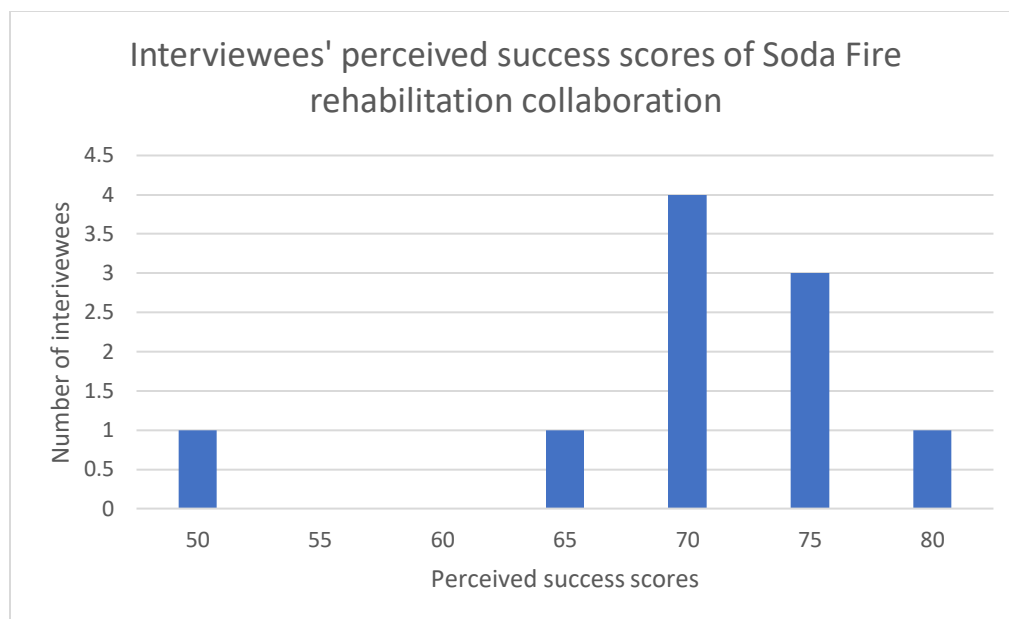


Figure 4.3. Histogram of interviewees’ perceived success scores of the Soda Fire rehabilitation collaboration.

Frequently, interviewees provided tangible outcomes resulting from the Soda Fire collaboration. An Oregon BLM employee mentioned that because the Soda Fire “*many of the things we learned in Soda are going to be used to change our ESR (Emergency Stabilization and Rehabilitation) handbook within BLM.*” In the same vein, an OSC employee stated that “*something that has probably resulted from the Soda Fire is the BLM is now bringing a point of contact from the IDL and IDFG to the table to create an ESR plan.*” Thus, lessons learned during the Soda Fire effort may be incorporated into future ESR efforts in the region and more individuals are providing input as to what those lessons may be. For instance, as this USFWS employee explained the USFWS is also more involved with the BLM as a result of the Soda Fire: “*Our relationships with agency partners have been strengthened through our efforts on the Soda Fire. One very strong and tangible example of that is we have now partnered with the BLM to co-locate three*

*USFWS positions in three BLM District offices to increase our capacity to partner in the same type of way.*” The Owyhee Rangeland Fire Protection Association (RFPA), involved in fire suppression rather than rehabilitation efforts, has also strengthened relations with agency partners since the Soda Fire. An Owyhee RFPA member voiced that *“to have the BLM and IDL get us more and better machinery is something that the Soda Fire really spurred up. It makes a huge difference when you have dependable vehicles you can go out there and fight fire with.”* Because of the positive outcomes resulting from the Soda Fire partners group, this approach to post-fire rehabilitation may become formalized with the state of Idaho. Employees of the Idaho BLM mentioned that while *“the Soda Partners group isn’t really formalized, it is starting to be formalized. The strategic group at the state office is taking what [X] did with Soda and ensuring that it happens on a statewide scale...They realized it was a cool thing.”* While many interviewees shared positive outcomes of the Soda Fire rehabilitation collaboration, there was also concern that the Soda Fire was a product of the socio-political climate at the time and that future fire responses might not be as comprehensive. While the Idaho BLM employees mentioned the potential for formalization across the state of collaborative efforts resembling the Soda Fire partners group, they also provided the caveat that *“Soda was a really unique project in a unique time and we were allowed to think outside the box and that’s probably why we had such a big partnership and collaboration, because it was an exciting time. And the follow-through on that has kind of dropped off. It’s unfortunate that everything we learned is kind of insignificant now.”* A USGS employee echoed this concern in saying, *“the real hope is that you do something like this for one project but the good principles and good partnerships are brought into subsequent projects, and I*

*haven't seen that happen.*" Some interviewees mentioned that shifting agency priorities, enforced via top-down processes from agency headquarters to field staffs, have impacted what they focus their time on; however, interviewees also mentioned bottom-up processes, such as individuals' capacity for engaging in post-fire collaborative processes regardless of restrictive top-down imperatives, as a possible solution.

#### *Opportunities for Top-down and Bottom-up Changes*

While some top-down processes inherent to land management agencies were described as restricting individuals' involvement in long-term collaborative efforts, interviewees also emphasized the power individuals have to forge these connections anyway. For example, an employee of the USFWS described how *"the agencies are not built to handle long-term commitments. The personnel, the funding streams, the policies aren't well adapted for that, so we need to change some of that...but the individuals need to try and take ownership for the long term too. I think if we expect more individually, that we can each individually make a difference."* Additionally, a USGS employee highlighted the importance of individual agency in forming post-fire rehabilitation efforts like that following the Soda Fire: *"Projects like this really come down to individuals and if individuals believe in something they are going to make it happen, irrespective of whether their time is specifically ascribed to it, because things like this require individuals to go way beyond what they are paid to do."*

## **Discussion**

The National Cohesive Wildland Fire Management Strategy, initiated in 2010, sets out to promote collaboration between governmental and nongovernmental agencies, individuals, and other interests in addressing landscape-scale wildland fire management



(Wildland Fire Leadership Council, 2014). This ‘all hands, all lands’ approach has gained momentum in the last decade but its success is dependent on collaborative relationships across land tenure boundaries (Charnley et al., 2017). One study of disaster response networks in response to a Swedish wildfire found that without collaboration resources are used inefficiently (Bodin and Nohrstedt, 2016). However, there is a dearth of wildfire related studies that have evaluated how stakeholders are working across connected landscapes (Bodin et al., 2019; Bodin and Nohrstedt, 2016; Charnley et al., 2017; Fischer et al., 2016; Hamilton et al., 2019), and to the authors’ knowledge none focus on rehabilitation or are in a rangelands context. Thus, while this research is a case study, it has wide applicability to other rangeland systems and can help elucidate capacity for collaboration in managing processes that cross jurisdictions indiscriminately, i.e. wildfire and invasive species.

According to interviewees, the Soda Fire rehabilitation collaboration was better than the status quo. However, even interviewees that were satisfied with the collaboration expressed that the ‘collaboration’ was mainly communication and not shared decision-making. In practice, ‘collaboration’ varied from shared decision-making, shared funding, and/or technical assistance. Using Mattessich et al.’s (2001) definitions of cooperation, coordination, and collaboration, we conclude that the Soda Fire ‘collaboration’ was largely coordination because leadership was not shared and resources were not pooled. Arguably, this ‘arm’s length’ posture may be the best strategy when there is a power imbalance between stakeholders because it minimizes the amount of time dedicated to procedural concerns while still allowing information sharing (Butler, 2013). Individuals within agencies engaging in collaborative efforts often have to negotiate boundaries of

knowledge, responsibility, and capacity (Orth and Cheng, 2019). In the context of the Soda Fire, or any multi-jurisdictional process, actors also have to negotiate across man-made jurisdictions. In Western rangeland wildfire rehabilitation, there are essentially three management processes occurring at once; those on private, state, and federal lands. Within the Soda Fire ‘collaborative’ management process the state and federal lands were effectively managed as one; however, the private lands process was separate because of funding constraints. With the BLM unable to fund private lands rehabilitation, other agencies coordinated assistance to landowners. The OSC, IDFG, and USFWS coordinated with the NRCS so that they could contribute toward a cost-share for spraying the first year, and the NRCS could do the same for seeding the following year on private lands. However, few landowners applied for this assistance, largely because they needed their private lands to feed cattle since their grazing allotments on federal and state lands had burned and required mandatory rest. Multiple interviewees mentioned that grassbanks (Gripne, 2005) or grasslands insurance would ameliorate the impact of wildfires on private landowners and allow them to participate more freely in treatments on their private lands. While the private landowners are ultimately deciding which treatments occur on their lands, those decisions are impacted by the BLM’s decisions on grazing resumption on federal lands. Additionally, the IDL is the ultimate authority for treatments on state lands, but because of the checkerboard nature of IDL (state) managed parcels within larger tracts of BLM land, they were greatly impacted by the decisions of the BLM as well. For better or worse, the BLM had the most power in this landscape rehabilitation, so they also had the highest capacity to serve as bridges to other agencies and entities. This finding is in accordance with past research examining the social

dynamics of post-fire responses (Faas et al., 2017). In this case the BLM encouraged other agencies to be part of the rehabilitation response. As a result, individuals within these other agencies were better able to understand the constraints the BLM operates under and learn more about how they can interface with the BLM in the future. This incremental individual learning can then contribute to increased institutional capacity for future fire events.

The state of inter-agency collaboration within the context of the Soda Fire rehabilitation effort is complex and varies by agency. For instance, the Oregon and the Idaho BLM were in communication but ultimately chose different treatments on their lands. It is beyond the scope of this study to assess the effectiveness of those treatments; however, managing lands differently within the area burned by a single fire obviates any potential benefits of cohesive landscape-scale management. Evaluating how best to coordinate agency management efforts across state lines is an avenue of research that still requires more exploration and is likely case-dependent. In the case of the Soda Fire, rehabilitation efforts in Idaho were a greater priority because of the burn area's proximity to the state capitol, the amount of lost Greater Sage-Grouse habitat, and the presence of an active ranching community and environmental interest groups. The combination of the pending sage grouse listing decision and the socio-political climate that incited collaboration also prioritized other burn areas in Oregon over those that burned during the Soda Fire.

Collaboration researchers often argue that crises can serve as windows of opportunity for bonds to be formed and action to take place (Olsson et al., 2004; Wondolleck and Yaffee, 2000). Certainly, new 'collaborative' relationships were forged

during the Soda Fire rehabilitation efforts and provided an opportunity for learning; however, the partnership mainly capitalized on established relationships from other management efforts. Wondolleck and Yaffee (2000) hypothesize that these established relationships from the past have a major impact on furthering future collaborative efforts. More recently, a study of wildfire response networks found that pre-existing relationships composed 54-82% of all collaborations (Bodin et al., 2019). Our study of the Soda Fire rehabilitation collaboration supports this finding. However, with high employee turnover rates, agencies need to support transitions in relationships so that associated collaborations can be maintained, thereby facilitating effective rehabilitation following wildfire.

## **Conclusion**

Increasingly, large-scale wildfires of more than 100,000 acres are burning Western U.S rangelands (Chambers and Pellant, 2008). These wildfires can have negative impacts on the landscape, including but not limited to: promoting plant community conversion to invasive annual grasses, adding stressors to wildlife populations, increasing erosional processes, and lowering the economic feasibility of a ranching livelihood (Pierson et al., 2011; Whisenant, 1990). Because wildfires burn irrespective of public and private land management boundaries, multiple agencies are sometimes tasked with post-fire rehabilitation on the same landscape, only separated by man-made boundaries. When lands impacted by a multi-jurisdictional fire are rehabilitated independently there can be a loss of landscape continuity that can impact ecological processes and eventually human systems. With increasing frequency and magnitude of large-scale multi-jurisdictional events such as wildfires, cascading events in linked social-ecological systems increase

connectivity at multiple scales and make collaboration imperative to our understanding of the complex system dynamics (Peters et al., 2007). As a result, understanding the strengths and limitations of inter-agency collaboration and opportunities for continued growth is critical.

For the 2015 Soda Fire rehabilitation effort we evaluated the state of collaboration, including the impetus for collaboration, how collaborative relationships were forged or established ones activated, and outcomes both tangible (e.g. management output) or non-tangible (e.g. learning). Certainly, there are systemic limitations both to collaborations between government agencies and collaborations between agencies and other entities (i.e. nonprofits, private landowners, general public, etc). These barriers to collaboration can include differences in organizational norms and culture, conflicting goals and missions, constrained resources, inflexible agency policies, funding streams, employee turnover rates, mistrust among stakeholders, and a culture of litigation. However, bottom-up processes, like individuals' power to initiate collaborations, should not be underestimated. Ultimately, effective collaborations happen between individuals once trust is established, so while the call for collaboration might ebb and flow due to external factors (i.e. socio-political climate), latent established relationships can be reactivated in new contexts regardless. Furthermore, through bottom-up processes, organizational culture can be an emergent property of incremental choices individuals are making. Thus, while top-down processes are often cited as a limitation to strengthening collaborative connections, bottom-up processes can counteract these constraints to a degree and work toward lessening them in the future.

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## CHAPTER V

### CONCLUSION

#### **Research Synopsis**

The three case studies presented in this dissertation assess the resilience of social-ecological systems (SES). Connectivity in a social-ecological system facilitates recovery after a disturbance in the ecological landscape or social sphere. Many ecologists focus on the ecological component of rangeland SES, but to sustain a resilient complex-adaptive system the social system, too, must be flexible enough to withstand unexpected shocks or stresses. In all three studies, I examine barriers to increasing the resilience of the specific SES with the ultimate goal of increasing capacity to sustain rangelands generally.

Survey, interview, and focus group data from the innovation adoption study showed that managers' adoption decisions for two rangeland management innovations that promote multi-agency monitoring and adaptive management efforts were impacted by factors at all levels of analysis: innovation traits, individual social capital, organizational, and external systems. All five of Rogers' (2003) innovation attributes – complexity, relative advantage, observability, compatibility, and trialability – were identified as being important for land managers' adoption of the WCRT. At the individual level, the IIRH interviews revealed that individuals from the BLM, NPS, and USFS sought rangeland management advice and ideas from within their agency and not from outside agencies. This finding suggests that, within this context, land managers may have more bonding and linking than bridging social capital. Networks with a lack of bridging social capital are susceptible to stagnant information pools that hinder innovation and change, leading to low adaptability and, ultimately, low resilience.

Funding streams and inflexible agency policy were hindering factors at the organization-level that were often cited by interviewees. Lastly, the external political system and fear of litigation from outside groups, which drives some of the organization-level factors, also stifled individual's ability to adopt innovations. Innovation adoption barriers at the individual, organization, external, and to a lesser degree at the innovation level, were all associated with lowered resilience. Considering that the innovations are designed to increase resilient management of rangelands, but their adoption is hindered by reduced social-system resilience, the innovations are caught in a paradox that will likely take time to resolve.

In the mule deer cross-boundary collaboration study, social-ecological network analysis revealed that a few key actors were responsible for brokering a majority of the collaborations. As such, this network may not be resilient to outside perturbations and may risk fragmentation with position vacancies and potential overburdening of key actors. Further research is needed to understand whether few individuals are brokering relationships by design or necessity.

In studying the social dynamics behind the Soda Fire collaborative rehabilitation efforts, some of the same individual, organization, and external-level barriers present in the innovation adoption study were again brought up by interviewees. Funding timelines and inflexible agency policies were pointed out as agency barriers to increased collaboration. High employee turnover rates within agencies were also proposed as a barrier to maintaining long-term collaborative connections. Perhaps most notably, national-level policy decisions, as influenced by the socio-political climate, can heavily impact the perceived need for and aim of local-level collaboration. The Soda Fire

collaborative effort was, in reality, more a coordination effort divided by land tenure (private, state, and federal) than a true collaboration. Even so, most interviewees found the level of communication to be greater than they typically receive and perceived several positive outcomes resulting from the effort. This positivity was tempered though by the impression that follow through was waning and that little would be learned from the rehabilitation effort long-term, partially because administrative priorities had shifted. Because resilience is dependent on learning from the past and applying those lessons to the future, this finding is a potential barrier to social-ecological system resilience.

The three studies of this dissertation are different enough that they provide unique insights, yet similar enough that some comparisons can be made across all three study systems. The social networks generated in each study show a range of manager connectivity. In the innovation adoption study, agency siloing effectively fragments the network so that the BLM, NPS, and USFS are not seeking advice from each other in making rangeland management decisions. Thus, there is a breakdown in inter-agency communication concerning rangeland management innovations. In the mule deer cross-boundary collaboration study, inter-agency communication was present but brokered by a few individuals, half of which are not employed by the dominant land management agencies (BLM and USFS) but by the state wildlife agency (UDWR). The Soda Fire collaborative rehabilitation effort study displayed the most inter-agency communication of the three studies. Certainly, some entities felt they were left out of the Soda Fire collaboration; however, there was communication of findings and some degree of participation from most local, state, and federal partners.

While not immediately apparent in the social networks, all three study systems displayed some level of hierarchy among land managers. In the innovation adoption study, managers often cited their immediate superiors as their only advice connections. In the mule deer cross-boundary collaboration study, hierarchy was less evident but collaborations within the dominant land management agencies were hierarchically structured. In the Soda Fire collaborative rehabilitation effort study, hierarchy was present across the private, state, and federal lands rehabilitation processes. As displayed in the social networks, many agencies had a presence in all three rehabilitation processes. However, this does not mean the same employee from that agency was collaborating in each of the three rehabilitation processes. In reality, the employees collaborating at the federal level were often delegating other employees to operate at the more site specific levels. The finding of hierarchy cuts across all three study systems, from the unconnected innovation adoption network to the highly connected Soda Fire network, and suggests that under the right circumstances collaboration can be achieved regardless of the current hierarchical organizational structure of U.S. land management agencies.

### **Research Limitations**

Two important methodological considerations were present in each of the three studies. Firstly, this dissertation is a comparative case study approach, using three separate social-ecological systems to evaluate communication and collaboration necessary for resilient rangeland management. Case studies are often criticized as myopic in focus and providing little basis for scientific generalization (Yin, 1984; Zainal, 2007). Acknowledging these potential constraints, case studies still have the benefit of providing an in-depth investigation of complex issues and are considered a robust research method

in many social science studies. Through case study methods, researchers are able to go beyond quantitative methods for a more holistic explanation of the social phenomenon of study (Zainal, 2007). While individual case studies may not be generalizable to other systems, case studies contribute to a body of scientific literature that does enrich our understanding of processes more generally.

The second methodological consideration is boundary specification for social network analysis (SNA). Defining network boundaries is a key potential pitfall of SNA that is often discussed in network analysis literature (Bodin and Prell, 2011; Borgatti et al., 2018; Marsden, 2005; B. L. Nowell et al., 2018; Zuckerman, 2003). When deciding how to bound a network, researchers must first determine which feature of the social-ecological system is their primary interest (B. L. Nowell et al., 2018). As such, there is no one ‘true’ way of bounding a network. It is largely dependent on one’s research question. In both the innovation adoption study and the mule deer cross-boundary collaboration study, I utilized an *actor characteristic approach* (B. L. Nowell et al., 2018) to network bounding. Interviewees were approached based on their job and/or affiliation to an applicable agency. The strength of this approach is that there is no assumption of relationship between nodes, so the resulting network can capture subgroups and isolates. The limitation of this approach is that it can confuse institutional effects with interpersonal dynamics. Because interviewees are, by definition, part of a certain agency, the network structure may reflect institutional bias as much as it reflects social dynamics (B. L. Nowell et al., 2018). Since my research questions largely focused on inter-agency collaboration and communication for these two studies, the network was bounded to exclude nonprofits and private landowners. For example, the Mule Deer Foundation



(nonprofit) was not directly incorporated into the mule deer study although the State of Utah's Watershed Restoration Initiative (DNR) was. While nonprofits and private landowners are impacting management, I concluded their impact was beyond the scope of these studies.

In the Soda Fire collaborative rehabilitation effort study, the *actor characteristic* approach was combined with an *event-based* approach to identify who would be considered in the network. These two approaches were combined because networks examining response to an event are often considered narrow in focus and are difficult to generalize to other events over time (B. L. Nowell et al., 2018). In this study, interviewees that were involved, or perceived they should have been involved, in collaborative efforts within the proximity of the study area before and after the Soda Fire were all potential interviewees. As such, nonprofits and private landowners were included in this study. Even with this more inclusive approach, boundary issues arose in determining which collaborations before and after the Soda Fire were considered within the spatial proximity of the burned area. Ultimately, any project within the jurisdiction of the Owyhee or Vale BLM District Offices was considered. Any network bounding decision is going to have strengths and limitations, but recognizing and reporting these can provide clarity for readers.

## **Research Contributions**

The research presented in this dissertation adds to natural resource collaborative management studies in important ways by contributing three case studies of collaborative/communicative capacity between land managers in the Western U.S. SES resilience relies on adaptive ecological and social systems yet more attention has been

given to the ecological component. Results from all three of these studies point to the critical importance of social processes in maintaining a resilient SES. Particularly, maintaining adaptive capacity in agencies and resource-dependent communities is a critical yet understudied aspect of a resilient SES.

As many collaboration scholars have discussed, agencies struggle with balancing bonding, linking, and bridging social capital (Cortner and Moote, 1999; Knight and Landres, 1998; Wondolleck and Yaffee, 2000). While developing a professional ethos and making a niche for oneself is advantageous to agencies, it also creates insularity that can preserve status quo management practices beyond their utility (Cortner and Moote, 1999). Thus, diversity has the advantage of fostering innovation up to the point that it makes bridging differences challenging (Knight and Landres, 1998). The three case studies of this dissertation give an in-depth examination of how individuals within agencies are navigating inter-agency relationships, identifying which obstacles are still present for further collaboration, and recognizing potential opportunities for abating these obstacles.

An important contribution that the innovation adoption study offers is in literature calling for adaptive co-management. Pinkerton (2007) combines Yaffee's (1997) and Ascher's (2001) conclusions on agency shortcomings to conceptualize five behavioral biases that hinder adaptive co-management. One of these biases is fragmentation of information and knowledge (Pinkerton, 2007). The innovation adoption study focused on this bias as it pertains to inter-agency innovation adoption and diffusion. Both the WCRT and the IIRH are designed to be common tools between agencies that would facilitate communication about landscape condition and encourage proactive management.

However, agency siloing and inflexible agency policies hinder sharing information via these tools.

The mule deer cross-boundary collaboration study provides a novel methodological approach for studying ‘fully articulated’ social-ecological networks (SENs), networks with distinct social and ecological nodes and connections within and between the social and ecological networks (Sayles et al., 2019). There are relatively few studies of fully-articulated SENs and methods to analyze these complex networks are still nascent. Combining participation co-efficient, z-score, brokerage, betweenness centrality, and degree measures to assess the level of collaboration with the SEN is a methodological approach that is novel and could contribute to further methodological advances in the future.

Another contribution to the literature is provided by the Soda Fire collaborative rehabilitation study. As previous studies of wildfire social networks have demonstrated, organizations have limited capacity to collaborate on wildfires and make choices in who they interact with (Bodin et al., 2019; Bodin and Nohrstedt, 2016; Fischer et al., 2016; Hamilton et al., 2019; B. Nowell et al., 2018). However, these studies were not conducted in a rangelands context and were not examining reaction to a single fire event. The Soda Fire rehabilitation effort is praised as a prime example of collaboration between agencies but shows the traits of coordination, rather than collaboration. Similar to Orth and Cheng (2019) I found that agencies are negotiating knowledge, responsibility, and capacity boundaries with each other. However, as demonstrated in Butler (2013), “arm’s length” collaborative dialogue, such as the coordination present in the Soda Fire, may be the most

advantageous when entities are negotiating a responsibility boundary because it allows for communication without complicated procedural concerns.

Both the innovation adoption study and the Soda Fire rehabilitation study show how national-level policy decisions can impact local-level collaboration and communication. National-level factors impact agencies' policy and culture that is then reflected in individuals' choices. This relationship is reflected in Brunson's (2012) conceptual model of rangeland social-ecological systems. Also included in this model and found through my dissertation, are 'bottom-up' influences that start with the individual and later impact national-level policies. Yaffee (1998) defines these 'bottom-up processes' as centripetal forces because they're internal factors that facilitate collaboration.

All three of my case-studies show the importance of individuals. In the innovation adoption study, innovation champions are key for initiating incremental changes that facilitate larger scale organizational changes. Similarly, within the Soda Fire rehabilitation study, collaboration champions are crucial for establishing and maintaining relationships across agency boundaries that will lead to emergent organizational-level changes. Lastly, the mule deer cross-boundary collaboration emphasized the importance the 'individual' plays in connecting a social-ecological network. Often focus is directed at national-level policies, which certainly impact individuals' decision-making; however, there is less focus on how individual agency employee decisions impact national-level policies through bottom-up processes. Thus, the most important contribution of this dissertation to literature on rangeland management is that individuals within agencies,

opposed to the agency as a whole, are a crucial and often understudied component of rangeland SES.

### **Recommendations**

While this study provides insight into Western land managers' levels of communication and collaboration, the research presented here also reveals several opportunities for further research and improved cross-boundary collaboration promoting social-ecological system resilience. The first recommendation from this work is for agencies to better utilize the information-sharing potential of tools like the WCRT and IIRH. Bestelmeyer & Briske (2012) identified shared knowledge systems as a key element of resilience-based rangeland management because generating and then sharing knowledge that guides adaptation is crucial to resilience. The IIRH promotes standardized condition assessment measures, and thus multi-agency understanding of landscape condition. However, in practice, the IIRH was used separately by agencies. In fact, interviewees expressed concern with how others in different agencies were using the IIRH indicators. This finding suggests that promoting an innovation does not insure that results are being shared in a productive way. Those developing inter-agency monitoring tools should not just promote diffusion of the innovation but also forums for those users to share knowledge gains.

Another key recommendation from this dissertation research is to increase redundancy in sparse networks in which collaborations are mediated by a few individuals, like that in the mule deer management SEN. However, caution should be taken to not create so much redundancy that there's homogenization of management strategies and a reduction in novel solutions. A related recommendation is to use an

organizing entity, such as the Watershed Restoration Initiative in Utah, to serve as institutional memory should the network become fragmented.

A fourth recommendation is for individuals within land management agencies to independently decide to be an innovation or collaboration champion. Large-scale institutional changes to such issues as funding streams, inflexible policies, and employee turnover rates all appear to be intractable problems from the perspective of the individual. Certainly, administration shifts, as influenced by the current socio-political system, can have rapid and drastic top-down impacts on institutional-scale issues like those mentioned above. However, there is a role for the individual to change agency culture through emergent bottom-up processes. For an innovation or collaboration to be successful, it requires at least one champion, and that's something that cannot be dictated via top-down processes. Ultimately, collaborations are between individuals, not agencies. Developing and maintaining trust with others across agencies, is an obtainable step the individual can take to incrementally change their agencies' culture.

Relatedly, a fifth recommendation is for agencies to in some way manage transitions in relationships. With high employee turnover rates, new relationships have to be forged fairly frequently. This is another potential opportunity for an organizing entity like the Watershed Restoration Initiative to informally introduce individuals from across agencies. However, further research should examine potentially novel opportunities for agencies to navigate these staff transitions while retaining trust and standing with fellow collaborators.

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## APPENDICES

## APPENDIX A

### ‘SOCIETY FOR ECOLOGICAL RESTORATION’ CONFERENCE FOCUS GROUP QUESTIONS (OCTOBER 2014) & INTERVIEW QUESTIONS (NOVEMBER- DECEMBER 2015) FOR THE WCRT

**Question 1.** How long have you been working in a position that requires you to make rangeland management decisions?

**Question 2.** In what way(s) are you involved in making decisions about rangeland restoration?

**Question 3.** Do you currently use any online resources to inform your management decisions?

**Question 4.** If so, in what ways do you currently use online resources to inform your decisions on rangeland restoration following wildfire or non-native plant invasion?

**Question 5.** How usable and reliable are the online resources you’ve seen for informing rangeland restoration decisions?

- Would including seasonal weather forecasting, wind erosion potential, and seedbed microclimate data improve the current online resources or complicate them to the point of being unusable and unreliable?

**Question 6.** If new weather-related online management tools were available to you, are there factors that might hinder your ability to use them – for example, political pressures, local traditions that are difficult to break, or economic constraints?

- If so, ask interviewee to elaborate on how those pressures or constraints could be withdrawn over time?

- Are there any other constraints on your decisions that might affect your ability or willingness to use such a tool?

**Question 7.** How would you suggest we introduce this tool to rangeland managers?

- If he/she does not come up with ideas and it is too silent, suggest workshops, articles in newsletters, job training, and word of mouth. See if the interviewee deems the suggestions practical.

**Question 8.** Are there any other suggestions about how we should proceed in creating and marketing this online resource?

**Question 9.** Once this tool is created, would you be interested in trying it out and suggesting further improvements?

**Question 10.** Are there other rangeland managers that you think we should contact?

## APPENDIX B

‘RESTORING THE WEST’ CONFERENCE SURVEY FOR THE WCRT (OCTOBER  
2016)

**Question 1.** What is your role in rangeland restoration (e.g. planning implementation, NEPA, etc)? Within this role do you make more ESR (emergency stabilization and rehabilitation) decisions or are you involved in more ‘proactive’ restoration decisions?

**Question 2.** Is this something you believe you would use to inform your management decisions? Why or why not?

**Question 3.** Where do you see this tool having the most utility (e.g., to learn why previous projects failed or succeeded, as a predictive technology to assist in current/future decision making, etc.)?

## APPENDIX C

‘RESTORATION OF SAGEBRUSH ECOSYSTEMS’ CLASS SURVEY FOR THE  
WCRT (APRIL 2017)

**Question 1.** What is your role in rangeland restoration (e.g. planning implementation, NEPA, etc)? Within this role do you make more ESR (emergency stabilization and rehabilitation) decisions or are you involved in more ‘proactive’ restoration decisions?

**Question 2.** Are the resources on this website something you believe you would use to inform your management decisions? Why or why not?

**Question 3.** Where do you see this tool having the most utility (e.g., to learn why previous projects failed or succeeded, as a predictive technology to assist in current/future decision making, etc.)?

**Question 4.** What do you believe is the criteria for a rangeland management innovation? If possible, list a couple examples of institutional, operational, or technological/methodological innovations you’ve adopted?

**Question 5.** If you listed innovations above, how did you come to adopt them? Was it through an independent decision in isolation of others, top-down decision, or did you observe successes using these innovations before adoption?

## APPENDIX D

‘RESTORATION OF SAGEBRUSH ECOSYSTEMS’ CLASS SURVEY FOR THE  
WCRT (MARCH 2018)

**Question 1.** What is your role in rangeland restoration (e.g. planning implementation, NEPA, etc)?

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**Question 2.** What percentage of your time is spent in emergency stabilization and rehabilitation? What percentage of your time in proactive restoration? Please give all answers out of 100.

ESR : \_\_\_\_\_

Proactive restoration : \_\_\_\_\_

Other : \_\_\_\_\_

Total : \_\_\_\_\_

**Question 3.** What, if any, relative advantage is there to using this tool compared to your current management protocol?

-5 = disadvantage to what I'm doing now

0 = about the same advantage as what I'm doing now

5 = good relative advantage to what I'm doing now

-5 -4 -3 -2 -1 0 1 2 3 4 5

Relative Advantage ()	
-----------------------	--

**Question 4.** Do you see the results of this tool and the subsequent management decisions based off of those results as being defensible in NEPA appeals or litigation?

-5 = Not at all defensible 0 = Neutral 5 = Good defensibility

-5 -4 -3 -2 -1 0 1 2 3 4 5






Defendability ()	
------------------	--

**Question 5.** Please estimate the extent to which the following factors would likely become a hindrance to your using the tool? Please select all factors on a sliding scale of how much that factor prohibits your adoption.

0 = no hindrance 10 = large hindrance

0 1 2 3 4 5 6 7 8 9 10

Time ()	
Funding ()	
Agency policy ()	

**Question 6.** Are there other factors, not mentioned above, that would become a hindrance to your using the tool?

---

**Question 7.** How do you foresee this tool changing how you recommend/implement treatments (methodological change)?

---

**Question 8.** How do you foresee this tool impacting agency policy (institutional change)?

---

**Question 9.** Where do you see this tool having the most utility (e.g., to learn why previous projects failed or succeeded, as a predictive technology to assist in current/future decision making, etc.)?

---

**Question 10.** Is this something you would use to inform your management decisions?

- ☐ Yes
- ☐ Maybe
- ☐ No

**Question 11.** If you tried the tool, how user-friendly did you find it?

0 = not at all user-friendly

5 = moderately user-friendly

10 = exceptionally user-friendly

0 1 2 3 4 5 6 7 8 9 10

Ease of use ()	
----------------	--

**Question 12.** If you have any other comments about the weather-centric restoration tool, please leave them here.

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## APPENDIX E

### INTERPRETING INDICATORS OF RANGELAND HEALTH (IIRH) INNOVATION

#### ADOPTION INTERVIEW QUESTIONS (JUNE - AUGUST 2017)

**Question 1.** What is your role/job description within your agency?

**Question 2.** What do you currently do to assess rangeland health?

**Question 3.** Have you used the 17 Indicators of Rangeland Health (IIRH) for assessing rangeland quality? If so, can you recall when you or your field office adopted this practice (month, year)?

If you are unfamiliar with IIRH, this is a good reference:

Pyke, D. A., Herrick, J. E., Shaver, P., & Pellant, M. (2002). Rangeland health attributes and indicators for qualitative assessment. *Journal of range management*, 584-597.

If they'd prefer I give a summary:

Basically, there are 17 indicators to assess 3 ecosystem attributes (soil and site stability, hydrologic function, and biotic function).

The 17 indicators are: number and extent of rills, presence of water flow patterns, number and height of erosional pedestals or terracettes, bare ground from Ecological Site Description or other studies, number of gullies and erosion associated with gullies, extent of wind scoured, blowouts, and/or depositional areas, amount of litter movement, soil surface resistance to erosion, soil surface structure and soil organic matter content, effect of plant community composition

and spatial distribution on infiltration and runoff, presence and thickness of compaction layer, functional/structural groups, amount of plant mortality and decadence, average percent litter cover and depth, expected annual production, potential invasive species, and perennial plant reproductive capability.

**Question 4.** If so, what techniques do you use to measure each of the 17 indicators? For this question, I'm most interested in whether your adoption of IIRH was complete or an adaptation.

**Question 5.** If you are not familiar with the 17 indicators or use/do something else, please tell me what you would consider to be an innovation (operational, methodological, technological, or institutional) designed to increase the resilience of rangelands? Please provide the approximate time you adopted that practice (month, year).

**Question 6.** For the 17 indicators of rangeland health assessment or your innovation mentioned in question #5:

What would you say is the leading factor that led to adoption?

- Literature search and independent adoption
- Required to adopt by agency policy
- Witnessed success in other field offices or at workshops, please provide names of manager/professional that introduced you to the innovation

(For this question, I am interested in whether your adoption of the IIRH or some management innovation was made at the individual, field office, or agency level

and whether adoption was experimental or required witnessing successes elsewhere first.)

**Question 7.** Do you perceive your agency adopts innovations from other agencies (NPS, USFS, UDWR, etc)? If so, what innovation adoption (IIRH or other) or changes to management resulted from this interaction?

**Question 8.** Whom do you go to for advice in making rangeland management decisions? Please specify individuals within and outside of your agency where applicable. The names of any individuals you provide will not be published or released in any way.

## APPENDIX F

CROSS-BOUNDARY MULE DEER MANAGEMENT INTERVIEW QUESTIONS  
(JUNE - AUGUST 2017)

**Question 1.** What is your role/job description within your agency?

**Question 2.** Do you view your agency and/or regional field office collaborates with other agencies (USFS, NPS, UDWR, etc) when it comes to mule deer management? If so, what agencies and how do you work with them to address problems or concerns with mule deer migrations and effects on vegetation?

**Question 3.** Are there individuals within these agencies you specifically work with when it comes to managing mule deer habitat? Please specify their name and agency if applicable. (I'm asking for this information so that I can create a collaboration network that can be overlaid on top of an ecological network of mule deer summer and winter ranges in the La Sal and Abajo region.)

**Question 4.** More generally, is there anything you have to say about inter-agency collaboration in your region?

## APPENDIX G

SODA FIRE COLLABORATION INTERVIEW QUESTIONS (NOVEMBER 2018 –  
MARCH 2019)

## SECTION 1: Introduction

**Question 1.** Where do you work?

**Question 2.** What state do you work in?

Options: Oregon, Idaho, both

**Question 3.** What is your role within restoration and/or management efforts?

**Question 4.** What do you believe should be the management priorities for the lands burned by the Soda Fire?

**Question 5.** How do you define successful restoration?

**Question 6.** How do you define collaboration? Is it information flow, joint projects, shared resources, etc?

**Question 7.** Do you gauge the success of a collaboration by the process or the output?

## SECTION 2: Before Soda Fire

**Question 8.** Using your definition of collaboration, with whom have you collaborated in the five years prior to the Soda Fire by year? Please be as specific as possible.

2010? 2011? 2012? 2013? 2014? 2015 up to fire?

*Example) 2012- John Doe, Idaho BLM, Owyhee field office, Range Conservationist*

**Question 9.** Who initiated each of these collaborations?

**Question 10.** Were each of these collaborations legally mandated or voluntary?

**Question 11.** How successful do you perceive each of those collaborations to be on a scale from 0 to 100 and why? 0 = Negative experience, 100 = Extremely successful, If

possible separate out the success of the collaboration from the resultant happiness of all the stakeholders. (In practice, scores for individuals were hard to acquire and most interviewees would only give a score for the overall success of the collaboration.)

*Example) Collaboration with John Doe & Amy Fischer, perceived collaboration success = 85, any additional details*

**Question 12.** How long were those collaborations or how long do you expect those collaborations to last?

*Example) Collaboration with John Doe, 2012-2014*

---

### SECTION 3: After Soda Fire

---

**Question 13.** Using your definition of collaboration, with whom have you collaborated since the Soda Fire by year? 2015? 2016? 2017? 2018? Include continuing collaborations initiated before the Soda Fire

**Question 14:** Who initiated each of these collaborations? Only include collaborations not mentioned in Section 2

**Question 15.** Were each of these collaborations legally mandated or voluntary? Only include collaborations not mentioned in Section 2

**Question 16.** How successful do you perceive each of those collaborations to be on a scale from 0 to 100 and why? 0 = Negative experience, 100 = Extremely successful, If possible separate out the success of the collaboration from the resultant happiness of the all the stakeholders. (In practice, scores for individuals were hard to acquire and most interviewees would only give a score for the overall success of the collaboration.)

**Question 17.** How long were those collaborations or how long do you expect those collaborations to last?



*Example) Collaboration with Jane Doe, 2015-current, funding runs out 2020*

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SECTION 4: Outcomes & Conclusions

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**Question 18.** Can you mention any management outputs or environmental outcomes, tangible or not, resulting from collaborations you've engaged in? Please explain.

**Question 19.** Are there other individuals I should speak with about the Soda Fire restoration efforts? Please list other individuals that were/are involved in managing the lands affected by the Soda Fire.

*Example) John Doe, Range Conservationist at Idaho BLM*

**Question 20.** Is there anything else you would like me to know about the rehabilitation efforts taking place after the Soda Fire?

## APPENDIX H

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***Figure 4.1. Burn perimeter of the 2015 Soda Fire, including land tenure and 2016 vegetation treatments***

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# GWENDŴR MEREDITH

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## EDUCATION

### Utah State University (USU)

Logan, UT

S. J. & Jessie E. Quinney College of Natural Resources

August 2019

Department of Environment and Society

Human Dimensions of Ecosystem Science and Management Ph.D. student

Advisor: Mark Brunson

GPA: 4.0/4.0

### Indiana University (IU)

Bloomington, IN

*Individualized Major:* Animal Behavior, Ecology, and Conservation BA

May 2013

*Minors:* Psychology, Biology

GPA: 3.9/4.0, graduating with Highest Distinction & Phi Beta Kappa member

## EXPERIENCE

### USU Socio-Ecological Systems Lab

Logan, UT

#### *Ph.D. Student & Researcher*

August 2014 - August 2019

- Conducted social science data collection using surveys, interviews, and focus-groups for the following dissertation or colleague collaborations:
  - Weather-Centric Rangeland Revegetation Planning
  - Management innovations for resilient public rangelands: Adoption constraints and considerations
  - Collaborative management of mule deer (*Odocoileus hemionus*) in southeastern Utah: an examination of the social-ecological network
  - Effects of wildfire on collaborative governance of rangelands - a case study of the 2015 Soda Fire
- Analyzed data using Qualtrics, UCINET, and RStudio.
- Supervised by Dr. Mark Brunson



## EXPERIENCE (CONTINUED)

### Kalahari Meerkat Project

Van Zyldrus, Northern Cape, South Africa

#### Research Assistant

May-September 2013

- Collected behavioral adlib and focal data on meerkats in the field twice daily
- Collaborated with other assistants at the research station
- Supervised by Dr. Tim Clutton-Brock at Cambridge University

### IU Animal Behavior Farm

Bloomington, IN

#### Research Assistant

January 2011-May 2013

- Studied the correlation between sociality and reproductive success in the Brown-headed Cowbird
- Collected behavioral data and conducted statistical analysis
- Completed my honors thesis: "Social Integration in Brown-headed Cowbirds, *Molothrus ater*"
- Supervised by Drs. Meredith West and Drew King, and Ph.D. student Gregory Kohn

## PEER-REVIEWED PUBLICATIONS

Sayles, J., Garcia, M. M., Hamilton, M., Alexander, S., Baggio, J., Fischer, A. P., Ingold, K., **Meredith, G.** & Pittman, J. (2019). Social-ecological network analysis for sustainability sciences: a systematic review and innovative research agenda for the future. *Environmental Research Letters*.

Hardegree, S. P., Abatzoglou, J. T., Brunson, M. W., Germino, M. J., Hegewisch, K. C., Moffet, C. A., . . . **Meredith, G. R.** (2018). Weather-Centric Rangeland Revegetation Planning. *Rangeland Ecology & Management*, 71(1), 1-11.

Kohn, G.M., **Meredith, G.R.**, Magdaleno, F.R., King, A.P., & West, M.J. (2015). Sex differences in familiarity preferences within fission-fusion brown-headed cowbird, *Molothrus ater*, flocks. *Animal Behavior*, 106, pp.137-143.

Dohme, R., King, A. P., **Meredith, G. R.**, & West, M. J. (2014). Is Female Visual Signaling to Male Song Socially Regulated in Brown-headed Cowbirds? *Ethology*, 121(4), pp. 327-334.

Kohn, G. M., King, A. P., Dohme, R., **Meredith, G. R.**, & West, M. J. (2013). In the company of cowbirds, *Molothrus ater ater*: Robust patterns of sociability predict reproductive performance. *Journal of Comparative Psychology*, 127(1), pp. 40-48.

Kohn, G. M., King, A. P., Dohme, R., **Meredith, G. R.**, & West, M. J. (2013). Robust autumn social attributes predict spring courtship skills in juvenile female brown-headed cowbirds, *Molothrus ater*. *Animal Behaviour*, 85, pp. 727-732.

## PEER-REVIEWED PUBLICATIONS (CONTINUED)

### Manuscripts in preparation:

- **Meredith, G.R.**, Brunson, M.W., Hardegree, S.P. Management innovations for resilient public rangelands: Adoption constraints and considerations
- **Meredith, G.R.**, Baggio, J., Brunson, M.W. Collaborative management of mule deer in Southeastern Utah: an examination of the social-ecological network
- **Meredith, G.R.**, Brunson, M.W. Effects of wildfire on collaborative governance of rangelands - a case study of the 2015 Soda Fire

## PRESENTATIONS AT PROFESSIONAL MEETINGS

### PRESENTATIONS

**G. Meredith**, M. Brunson, “Effects of wildfire on collaborative governance of rangelands – a case study of the 2015 Soda Fire”, International Symposium on Society and Resource Management, Oshkosh, Wisconsin, 2019.

**G. Meredith**, J. Baggio, M. Brunson, “Inter-agency collaborative management of mule deer in Southeastern Utah: Examining the social-ecological network”, International Symposium on Society and Resource Management, Salt Lake City, Utah, 2018.

**G. Meredith**, M. Brunson, “Inter-agency management of rangelands: innovation adoption and scale mismatches within networks”, Student Research Symposium, Utah State University, 2017.

**G. Meredith**, M. Brunson, “Inter-agency management of rangelands: innovation adoption and scale mismatches within networks”, Environment and Society Symposium, Utah State University, 2017.

**G. Meredith**, M. Brunson, “Innovation adoption in rangeland management: development of a weather-centric restoration tool”, Student Research Symposium, Utah State University, 2016.

**G. Meredith**, M. Brunson, “Managers use of external information sources for restoration decisions”, Society for Range Management Conference, Corpus Christi, Texas, 2016.

**G. Meredith**, G. Kohn, M. West, & A.P. King, “Social integration in Brown-headed Cowbirds, *Molothrus ater*”, Honors Research Symposium, Indiana University, 2013.

### POSTERS

**G. Meredith**, M. Brunson, “Inter-agency management of rangelands: Legal barriers and learning effects on innovation adoption”, Resilience Conference, Stockholm, Sweden, 2017.

## PRESENTATIONS AT PROFESSIONAL MEETINGS (CONT.)

**G. Meredith**, J. Baggio, M. Brunson, “Inter-agency collaboration in natural resource management: The case for exponential random graph models”, Resilience Conference, Stockholm, Sweden, 2017.

**G. Meredith**, M. Brunson, “A climate-based rangeland management tool – using manager input to increase adoption success”, Student Research Symposium, Utah State University, 2015.

**G. Meredith**, G. Kohn, M. West, & A.P. King, “Social integration in Brown-headed Cowbirds, *Molothrus ater*”, Animal Behavior Conference, Indiana University, 2013.

## TEACHING EXPERIENCE

### Utah State University

Logan, UT

#### *Instructor of Record*

Developed curriculum for upper-level online and classroom instruction,  
Taught materials, Facilitated class discussions, & Assigned grades for ~25 students each semester

- Geography of Utah (online & classroom) Fall 2018/2019 & Spring 2019

#### *Graduate Teaching Assistant*

Led discussions, Taught classes in instructor’s absence, & Assigned grades for 74 students

- Human Dimensions of Natural Resource Management Fall 2016

### Indiana University

Bloomington, IN

#### *Undergraduate Teaching Assistant*

Assisted the instructor, Dr. Susan Hengeveld, Instructed students in identifying Indiana birds, Led discussions, Facilitated students, & Assigned grades for ~35 students

- Ornithology Spring 2013

## UNIVERSITY AND DEPARTMENTAL SERVICE

### Utah State University

Logan, UT

#### *College of Natural Resources Graduate Student Council, Chairman*

Fall 2017 - May 2019

Managed monthly meetings of a thirteen-member council within my college that worked to bring grad student issues to the attention of the college and university. In April 2019, I was awarded the “Outstanding Personal Contribution Award” from USU’s Student Association.

## UNIVERSITY AND DEPARTMENTAL SERVICE (CONT.)

*USU Grad Student Council, Natural Resources Representative* Summer 2017 – May 2019  
Served as liaison between the College of Natural Resources and Utah State University for grad students, Advocated for increased grad student health insurance options and transparency in university policies

*Empowering Teaching Excellence: Preparing Future Faculty Committee* Fall 2018 – May 2019  
Researched and communicated what resources graduate instructors desire, Co-developed and promoted a teaching certificate program for grad students within departments not offering any training

*Environment & Society Graduate Student Representative* Fall 2016 - Spring 2017  
Participated within the College of Natural Resources Graduate Student Council, Attended Environment & Society departmental faculty meetings, Served as the liaison between department and college for Environment & Society grad students

*Ecology Center Speaker Selection Committee Co-chair* March 2016 - May 2017  
Organized operations of USU's Ecology Seminar Series, bringing researchers from all over the world to our campus to present their research

*Ecology Center Speaker Selection Committee Member* March 2015 - March 2016  
Helped select and rank potential speakers for USU's Ecology Seminar Series

*Ecolunch Coordinator* Fall 2015  
Organized speakers for weekly Ecology lunchtime talks targeted toward graduate students

## COMMUNITY SERVICE

**Stokes Nature Center** Logan, UT  
*Naturalist Educator & Preschool Substitute Teacher* January 2018 – September 2019  
*Volunteer of the Month – June 2018*  
Designed and taught curriculum for pre-school through fifth grade students in watershed hydrology, riparian habitats and associated macroinvertebrates, and the rock cycle.

## TRAINING

**Social Network Analysis Short Course** Annapolis, MD  
*National Socio-Environmental Synthesis Center* July 2018

**USU Grant Proposal Writing Workshop** Logan, UT  
*Utah State University* September 2017

## TRAINING (CONT.)

**Emma Marris Science Writing Workshop**  
*Utah State University*

Logan, UT  
 March 2017

**Introduction to Social Network Analysis**  
*LINKS Center for Social Network Analysis*  
*University of Kentucky*

Lexington, KY  
 June 2016

## FELLOWSHIPS & GRANTS

**Graduate Enhancement Award**  
 Utah State University

Summer 2019

**Redd Center for Western Studies**  
 Summer Grant for Upper Division and Graduate Students

Spring 2018

**S.J. & Jessie E. Quinney Foundation**  
 Doctoral Fellowship

Fall 2014 –Fall 2018